Research & Technology Report

1996

Office of Equal Opportunity Programs
Minority University Research and Education Division

UNIVERSITY RESEARCH CENTERS

The University Research Centers (URC) at Minority Institutions program seeks to achieve a broad-based, mainstream, competitive aerospace research capability among the Nation's Historically Black Colleges and Universities (HBCU) and Other Minority Universities (OMU). The goals of the program are to:

- Foster new science and technology concepts
- Expand the Nation's base for aerospace research and development
- Develop mechanisms for increased participation by faculty and students of HBCUs and OMUs in mainstream research
- Increase the production of disadvantaged students, who are U.S. citizens and who have historically been underrepresented, with advanced degrees in NASA-related fields

Now entering its 6th year, the URC program funds research centers at 11 HBCUs and 3 OMUs. This report summarizes the activities of these URCs during the Summer 1995 and Academic Year 1995–1996 reporting period. During this period, 253 professional-level investigators were involved in research projects at the URCs, including 197 faculty members, 36 research associates, and 20 postdoctoral fellows. A total of 483 students—296 undergraduate and 187 graduate students—participated in these research activities. The research accomplishments were documented in 260 refereed papers or book chapters published during this time period. Significantly, 77 students were authors or co-authors of these publications. An additional 103 papers or book chapters, including 27 student authors or co-authors, were accepted for publication during this period. The broader research community was informed of this work through 352 technical presentations given at national and international conferences, including 123 presentations given by students.

During the reporting period, the URCs were able to leverage their NASA MUREP funding of $19.6 million to an additional $12.0 million in research support, $4,134,269 from other NASA programs, and $7,880,802 from other agencies.

A major goal of the URC program is to increase the number of disadvantaged and underrepresented students receiving advanced degrees and entering careers in NASA-related fields. The 483 students involved in the research projects at the 14 URC's during the reporting period represent an 85 percent increase from the 261 students involved during the previous year. Much of this increase resulted from the continued maturation of the seven URC's first funded in Fiscal Year (FY) 1995.

Of the 483 students, 296 (61 percent) participated at the bachelor's-degree level, 153 out of 483 (32 percent) participated at the master's-degree level, and 34 out of 483 (7 percent) participated at the doctoral degree level. Of the participating students, 96 percent were members of an underrepresented ethnic minority group.

During the reporting period, 106 students obtained degrees: 73 bachelor's degrees; 27 master's degrees; and 6 doctoral degrees; and 95 percent of the graduates were members of an underrepresented minority group. Nineteen of the graduates were employed in NASA-related fields: 12 bachelor's-degree graduates; 4 master's-degree graduates; and 3 doctoral-degree graduates.

Forty-three of the 73 bachelor's-degree graduates (59 percent) planned to pursue graduate degrees, while all of the 27 master's-degree recipients planned to pursue a doctoral degree. In total, 85 percent of the students receiving degrees remained in the pipeline by pursuing for the next degree or by accepting employment in a NASA-related field.

The University Research Centers perform scientific and/or engineering research relevant to the four NASA Strategic Enterprises: Aeronautics and Space Transportation Technology; Human Exploration and Development of Space; Mission to Planet Earth; and Space Science. Reports from each of the University Research Centers, arranged according to the primary Strategic Enterprise that they support, follow.

Aeronautics and Space Transportation Technology

High Performance Polymers and Ceramics Research Center

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Date of Original Award: 1992

INTRODUCTION

The High Performance Polymers and Ceramics (HiPPAC) Research Center has developed the infrastructure and research focus necessary to carry out cutting-edge research and development in high-performance polymers and composites, in order to address problems important to NASA's Aeronautics and Space Transportation Technology Enterprise. The Center is focused on fundamental and applied research and the attendant human resources development in chemistry, physics, materials science, and engineering.

RESEARCH ACCOMPLISHMENTS

Synthesis, Characterization, Properties, and Processing of Polyimides

Polyimides are advanced materials that have good high-temperature stability, excellent dimensional stability, and excellent mechanical, electrical, and chemical resistance properties. They can be molded for applications, including those in jet engine parts, glass fiber-reinforced blocks, and printed wiring boards, and produced as films for use in electric motors, flat flexible cable, and magnetic wire insulation. Additionally, they can be applied as coatings on semiconductor devices and electrical components. However, the use of polyimides in aeronautics programs is limited by the requirements of extreme processing conditions caused by very high glass transition temperatures and high melt viscosities. To improve on the processability of polyimides and to extend their use in composite applications, HiPPAC investigators have synthesized and incorporated a series of new bisimide processing additives into Langley Research Center (LaRC) Thermoplastic Polyimide (TPI) and Ultem™ polyimides. These processing additives significantly lower the glass transition temperatures, flow temperatures, and melt viscosities—thus allowing for easier processing—while producing only minimal effects on the chemical resistance and mechanical properties of the polyimides.

Preparation and Characterization of Non-Linear Optical (NLO) and Photorefractive Polymers

Polyimides that exhibit NLO behavior have applications in fast electro-optical switches and modulators for optical communication, laser frequency conversion, and optical switches for ultra-fast computation. Polyimide-based photorefractive materials are the principal candidates for applications, including high-density optical data storage and image processing. We have covalently incorporated 2-(4'-nitrophenyl)-4,5-bis(4'-methoxyphenyl)-imidazole, a robust NLO chromophore, into polystyrene-co-methyl methacrylate (SMMA) and 6-FDA-4,4'-diamino-3,3'-dihydroxybiphenyl polyimides, which produce new polymers that exhibit good electro-optical behavior. Tricyanovinyl-substituted triarylamines have been prepared as new dual-functional photorefractive materials, serving as both the NLO chromophores and as sites for charge generation and transport.

Smart Material Systems

Smart material systems is an emerging technology area aimed toward the development of material systems and structures that can rearrange themselves to their optimum functional capabilities or that can adapt to external stimuli by using inherent or integral functional elements, such as sensors, actuators, and controllers.

We have surveyed and evaluated new coupled-field finite elements available in commercial finite element codes. The effect of temperature sensitivity of piezoelectric actuators on high-performance piezoelectric composites has been studied by finite element analysis. It was found that piezo materials are sensitive to temperature variation and that this can noticeably affect the actuation response of the composites in which they are embedded. An experimental setup for characterizing the converse piezoelectric effects of piezopolymer films has been designed and fabricated.

We have also demonstrated experimentally that a piezoceramic micro-actuator bonded in the vicinity of a bolted joint in a structure can be used to detect stiffness degradation of the joint. The application of these integrated microsensors/micro-actuators provides an opportunity to monitor the integrity of large structures, including trussed systems such as bridges, dome roofs, antennae, and the Space Station, by continuously monitoring the

dynamic response signatures of intelligently-induced and electronically-captured oscillations.

Fabrication and Mechanical Characterization of Polymer-Based Composites
Researchers are also working on the design, fabrication, processing, durability, testing, and modeling for life-time prediction and aging of polymer matrix composites (PMCs) and hybrid metal composite laminates (HMCLs). We have focused on fundamental materials issues at the microscale and on interfaces, analytical modeling, thermomechanical fatigue testing and evaluation, and constitutive and damage modeling. The use of PMCs and HMCLs in place of metals results in significant weight savings, leading to improved performance and fuel economy, as well as increased aircraft range or passenger/payload capacity.

The HiPPAC Research Center has developed the capability to prepare hybrid metal composite laminates up to 12 by 12 inches. Thermomechanical analysis (TMA)/stress strain has been used to measure linear and volumetric changes in the dimensions of small "lap joints" of the laminates as a function of applied force, time, and temperature. The storage modulus, E′ (a measure of the stiffness or rigidity of the laminates), and the loss modulus, E′ (a measure of the degree to which the laminates dissipate mechanical energy by converting it to heat through molecular motion) have been measured. Two-dimensional infrared mapping has been utilized to investigate the mode of delamination of the polymer from the metal substrate in failed joints.

RELEVANCE TO NASA STRATEGIC ENTERPRISES
Smart material systems can be implemented to such aerospace applications as health monitoring, active damage control, and active vibration control of aerospace structures. Polymeric NLO and photorefractive materials have applications in the development of "flight by light" systems, as well as in optical computing and information storage. The fabrication of polymer-based composites has applications important to the aerospace industry; it provides lightweight structural materials possessing superior strength/weight and/or modulus/weight characteristics for applications in future aerospace structures, including aircraft, missiles, and spacecraft.

BENEFITS TO SOCIETY
The research and technology under development in this project will play a vital role in ensuring the safety, environmental compatibility, and productivity of air transportation and space systems, as well as enhance the security and economic health of the Nation.

STUDENT ACHIEVEMENTS
The HiPPAC Research Center has contributed to increasing the number of disadvantaged and underrepresented students at Clark Atlanta University who are U.S. citizens, with students receiving B.S. degrees in science or engineering, M.S. degrees in chemistry or physics, and Ph.D. degrees in chemistry.

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Center for Nonlinear and Nonequilibrium Aeroscience

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Date of Original Award: 1992

INTRODUCTION
The Center for Nonlinear and Nonequilibrium Aeroscience (CeNNAs)conducts research on the dynamics and aero-thermo-chemistry of gases and materials relevant to the Aeronautics and Space Transportation Technology Enterprise. The research is aimed at new insights into and new diagnostic procedures for turbulence and molecular relaxation processes in compressible neutral and ionized gases, aeroacoustics, propulsion dynamics, combustion, and heterogeneous nucleation. This also addresses programs of research on the characterization of stressed materials, film deposition processes, and the fundamental physics of electron and atomic collisions in the reentry regime.

RESEARCH ACCOMPLISHMENTS
Turbulence Modification of Nonequilibrium Condensation Processes
Heterogeneous nucleation and the subsequent droplet and crystal growth play a critical role in the contribution from polar stratospheric clouds (PSC) and vapor trails to atmospheric environmental concerns, as well as in the development of ice crystals on environmentally exposed aerofoils. Yet, the best growth rate theories are essentially ad hoc and/or empirical, with very weak experimental confirmation of underlying physical principles. We have begun to test and extend these theories. We have found a new clear dependence of droplet size on the strength of turbulence. Furthermore, when the rate of droplet growth is measured by observing the change in droplet size at two locations,

we find that the rate of change of droplet size also depends on the Reynolds number.

Direct Estimation Velocimetry for Measurements of Reynolds Stresses and Vorticity

A rank ordering of modeling approximation techniques for strong turbulence requires a dedicated relationship between theoretical approaches and experimental facilities. We have provided such a testing ground and have confirmed the applicability of our new diagnostic procedure, Direct Estimation Velocimetry (DEV), to turbulent compressible flow. Using DEV, we have performed simultaneous measurements of density, vorticity, and all components of velocity from laser-induced fluorescence at a data rate in excess of 2 MHz in a turbulent supersonic free shear layer. Our data show clear evidence of vanishing triple correlations—the averages of triple correlation terms $<r'u'v'>$ and $<r'u'w'>$ in consecutive time intervals. The average value is 0.029 ± 0.04, which is statistically consistent with the prediction of a value of zero for the triple correlation. These measurements offer a first confirmation of the validity of predictions in the theoretical approach, which suggests that macroscopic turbulent transport may be determined by microscopic molecular phenomena.

Role of Streamwise Vorticity on Mixing and Noise Characteristics of Supersonic Jets

Recent research has suggested that the addition of streamwise vorticity, or swirling flow, enhances the mixing of hot jet exhaust gases with the colder ambient air, resulting in a reduced infrared (IR) signature for fighter aircraft; it is also expected to significantly reduce the side-line noise from supersonic jet engines. To this end, a unique diamond-shaped, converging-diverging (c-d), Mach 2 nozzle was designed for a detailed investigation of the effect of significant streamwise vorticity on the acoustic and IR characteristics of supersonic jets. The diamond-shaped nozzle geometry was chosen because it was expected that the sharp corners of the diamond nozzle would lead to the creation of significant streamwise vorticity and subsequently to a modification of the mixing and acoustic properties of the jet. In addition, the high nozzle area-to-perimeter ratio of the diamond nozzle leads to minimal thrust losses. These factors make the diamond nozzle an attractive choice for further exploration.

We find that the presence of distinct "rippled" structures along the jet periphery is clearly visible in the laser light sheet images of the jet cross-sectional plane. These images, together with the results of pressure surveys conducted in the jet periphery, provide convincing evidence of the presence of significant streamwise vorticity in the periphery of the diamond-shaped jet. This increased the local thickness of the shear layer, while only moderately influencing the jet diffusion rate. However, the effect of vorticity on the far-field noise was fairly significant; for a hot jet, a 5-decibel reduction in jet side-line noise was measured when compared to the noise properties of conventional round jets.

Thermally Induced Stress Measurement and Load Relaxation

The purpose of this project is to characterize advanced materials for all ranges of temperatures and strain rates and to arrive at unified constitutive relations. A new technique of measuring real-time, whole field displacement gradient with a resolution of 0.5 meter has been developed. The measurements take place in the heating chamber of an environmental scanning electron microscope. This technique has been applied to the matrix of a Ti-24Al-11Nb composite reinforced with SiC fibers.

The relaxation data for a wide strain rate range have been measured and analyzed. Upon the completion of a relaxation test, the measured stress is allowed to reduce by a substantial amount. In this set of experiments, the specimen was loaded to the same superplastic strain-rate until the next strain level was obtained. We find that the stress increases systematically during both strain-rate change tests and load relaxation experiments. A constant strain-rate test curve is obtained, which represents the true stress strain state for the imposed strain rate ($5 \times 10^{-4} sec^{-1}$). This procedure allows us to determine the set of all steady-state stress values for a particular imposed strain rate at different strain values.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

The CeNNAs program is now organized to aggressively support the Aeronautics and Space Transportation Technology Enterprise. Specifically, our research on the turbulence modification of condensation may potentially provide the control of icing onset crystal sizes and growth rates in trails and aerofoils. The research on enhanced mixing through turbulence-mode manipulation and countercurrent dynamics may potentially provide improved efficiency in air-breathing subsonic propulsion systems. The research on natural closure and the possibility of inverse energy cascade in compressible turbulence may provide faster, cheaper, and more accurate physical models for turbulent flow and computer simulations. Our research on noise reduction in jets using vorticity bursts manipulation and diamond-shaped nozzles may provide improved efficiency, reduced visibility, and improved environmental impact in air-breathing supersonic and hypersonic propulsion systems. Finally, our research on the possibility of quantum mechanical signatures in turbulence

may provide a new generation of flow diagnostics using direct molecular-based turbulence phenomenology.

STUDENT ACHIEVEMENTS
During the course of the research sketched above, undergraduate as well as graduate students have made significant and noteworthy contributions. This includes cases where undergraduates were included as co-authors, graduate students participated in the successful acquisition of new research funds, and one graduate student received his Ph.D. degree in mechanical engineering.

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NASA Center of Research Excellence (NASA-CORE)

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INTRODUCTION
The Center for Aerospace Research conducts interdisciplinary research to develop techniques and analytical and design tools that will aid in the design of next-generation supersonic aircraft, hypersonic vehicles, and spacecraft. Five research groups (Aerospace Structures, Controls and Guidance, Computational Fluid Dynamics (CFD), Human-Machine Systems Engineering, and Propulsion) conduct innovative research for the development of new technologies in spacecraft and high-speed aircraft design. Our mission is to educate and train socially and economically disadvantaged students in aerospace engineering and Research, and also to enhance opportunities for socially and economically disadvantaged faculty who are U.S. citizens in aerospace engineering and technologies professions, in order to establish a strong research capability and to develop a robust systems engineering tool with a strong interdisciplinary research focus in support of NASA's mission.

RESEARCH ACCOMPLISHMENTS
In Aerospace Structures, we have developed a new nonlinear technique based on geometrically exact structural models that account for geometric nonlinearities (large rotations, displacements, and strains) and three-dimensional stress effects. The outcome of this research is a general total-Lagrangian finite-element code named GESA (geometrically exact structural analysis), which has been validated by experimental data and known theoretical solutions. This technology has potential applications in the prediction of large deformations of high-speed aircraft and spacecraft structures and will therefore provide aerospace structural engineers with a new design tool to aid them in better designing aircraft and spacecraft structures for high-speed vehicles. We have also developed predictive tools to monitor the health of aging aircraft and built-up and composite-repaired structures.

In Guidance and Controls, we are investigating aircraft stability and performance behavior with varying aerodynamic parameters. We have focused on two research topics: dominant pole assignment (DPA) for linear uncertain systems and linear quadratic optimal bode plots (LQOBP), which provides another solution to Kalman's inverse problem in terms of gain and phase margins. Ordinarily, it is difficult to analyze the stability and performance characteristics of aircraft with parameter variations. Using DPA and LQOBP, we are addressing the effects of parameter variations on the stability and performance characteristics of the aircraft.

In Human-Machine Systems Engineering, we are conducting research to address human operator (pilot) characteristics that impact the handling qualities of high-speed aircraft. The focus of our research here is on modeling the human operator interacting with a complex work system: in discrete and continuous (compensatory and pursuit, and stimulus-response [S-R] compatibility) tasks; and the effects of saccadic eye movement in visual information search and induced motion changes during task performance on pilot workload. Results obtained show the compensatory gain time of the human operator to be 0.75 ± 0.5 sec; occurring with varying crossover frequencies and phase angles between 63° and 70°. It was also shown that human operators respond differently to signal pairs and the manners in which S-R signals are presented. It has been found that induced motion changes affect human

Aerospace and engineering staff and students pose with the statue of Ronald E. McNair in front of the College of Engineering.

workload and degrade performance. In addition, a quantitative relationship among workload, task complexity, and system dynamics was derived.

In CFD, we focused our research on the following topics: development of compressible dissipation turbulence models in high-speed flows; implementation of boundary layer wall function methodology; experimental and computational investigation of air-breathing propulsion/airframe integration for waverider design; and study of fluid/structure interactions and flutter of high-speed vehicles. We have developed a new "eddy viscosity transport" model for turbulent flow prediction to provide more accurate surface pressure, skin friction, and heat transfer characteristics and have obtained a numerical solution of hypervelocity flow through a scramjet (supersonic ramjet) combustor for hypersonic vehicle propulsion. In addition, we conducted interdisciplinary research through the fluid/structure/control analysis of (panel) flutter. Such interactions have a profound effect on the behavior of the panel or aircraft surface.

Research activities in propulsion are relatively new to our core research program. The initial research thrust is in two broad areas: airframe/engine integration involving multidisciplinary design and optimization (MDO); and engine cycle analysis for High-Speed Civil Transport (HSCT) and hypersonic vehicle configurations. In MDO, we are developing methodologies for mathematical operations, which include model reduction and approximations, optimization, and sensitivity analysis to analyze the multidisciplinary effects of coupled disciplines. This will enable us to determine the effects of aerodynamic parameters, such as Mach number variations, on propulsion performance. A second application of MDO is fluid/structure/propulsion/control interaction, which strongly affects the performance and handling characteristics of aircraft. The effort here is to develop methodologies to optimize the aerodynamic characteristics from analytical models. This analysis approach allows for the development of high-fidelity models utilizing computational modules.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

The structural technologies being developed are very important to the structural technology goals of the Aeronautics and Space Transportation Technology Enterprise. The Human-Machine Systems Engineering results have wide applications in ongoing NASA research computational models for human factors and research on human-computer interface (Johnson Space Center) and human factors/crew performance research (Ames Research Center). The benefits of the research include a better understanding of the complex work domain and the impact on human-automated system interface, and an assessment tool for human performance in complex systems that include multimodal interface and group and collaborative (team) dynamics. The research in CFD will enable an accurate prediction of the behavior and design of the structure under adverse conditions to prevent catastrophic failure. The results of research in propulsion and the derived technologies have potential applications in HSCT and hypersonic vehicle design.

BENEFITS TO SOCIETY

The outcome of this research will enable the design of controllers that will greatly enhance the stability and performance of high-speed aircraft. This technology will have wide application in both commercial and military aircraft, with a potential benefit to the traveling public.

STUDENT ACHIEVEMENTS

Under National Science Foundation fellowships, two graduate students spent the 1996 summer at Japanese Space Agency laboratories.

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Center for Autonomous Control Engineering

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Date of Original Award: 1995

INTRODUCTION

The NASA Center for Autonomous Control Engineering (ACE) at the University of New Mexico believes that to have a positive influence on the future of scientific research, engineering development, and the world of the 21st century, it must be committed to opening scientific and engineering communities to all persons. Therefore, the main goal of ACE is to increase the opportunities and possibilities of science and technology education and research to the minority populations of our society. ACE is committed to augmenting diversity in science and engineering, while enhancing public understanding of science and engineering and the ethics in these fields. To accomplish its mission, ACE will strive to set aside those barriers encountered specifically by individuals from disadvantaged

and underrepresented groups. Those who seek to become engineers or scientists, or to enhance their current training as such, can look to ACE as a valuable resource in which to progress and thrive in these professions.

RESEARCH ACCOMPLISHMENTS

ACE has a dual commitment to excellence in research and educational opportunities for students. The research supported by ACE has resulted in the publication of 6 books, the appearance of 12 articles in refereed technical journals, and the presentation of 60 conference papers. The research conducted by ACE has also resulted in a U.S. patent based on fuzzy logic technology to enhance color prints from video sources. This patent is the first in the State of New Mexico in fuzzy logic technology.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

The research projects sponsored by ACE support all of the NASA Strategic Enterprises, with particular emphasis on:

- Remote sensing and satellite image enhancement using fuzzy logic support Mission to Planet Earth.
- Fuzzy logic and neural network control algorithms for aircraft landing and takeoff, aircraft body surface fatigue research, and approximate finite element meshing using fuzzy surface tessellation support Aeronautics and Space Transportation Technology.
- Intelligent rover technology, the sharing of research equipment over the Internet, and sensor fault detection and accommodation using causal probabilistic networks for autonomous control systems support the Human Exploration and Development of Space.

BENEFITS TO SOCIETY

ACE is committed to creating commercial products for the national economy. To this end, it has established a commercialization center. A New Mexico corporation called MediaTronix has been established to handle the commercialization efforts of ACE. Its first product slated for release is a fuzzy logic chip for enhancement of color prints from videos and 35-mm film.

STUDENT ACHIEVEMENTS

To date, ACE has graduated two doctoral students (one African American and one Hispanic American) and three students at the master's level (one Native American and two Hispanic Americans). One doctoral student is now working at the Jet Propulsion Laboratory (JPL), and the other is considering an offer from MIT Lincoln Laboratory. A female master's graduate has accepted an offer from Lockheed Martin Federal Division in Philadelphia. The ACE students have presented the results of their research at international symposia. Three students have received Best Paper Awards at the World Automation Congress, and three other students are expected to receive Best Paper Awards at the IEEE International Conference on Robotics and Automation (the world's most prestigious conference in robotics). Finally, one ACE master's graduate is in the process of starting his own company.

Master's students graduated from ACE

Additional NASA Enterprise Areas: Human Exploration and Development of Space, Mission to Planet Earth, and Space Science

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Human Exploration and Development of Space

NASA/FISK University Center for Photonic Materials and Devices

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INTRODUCTION

The NASA/Fisk University Center aims at performing research and developing technologies relevant to NASA's mission, focusing in the field of photonics. Research in photonics has made possible the development of new technologies that have produced revolutionary changes in communications, computing, robotics, medicine, environmental control, and many industrial processes. Additionally, the potential reputation of the center will attract an increased number of disadvantaged and underrepresented students, both graduate and undergraduate, and will motivate them to pursue careers relevant to the NASA mission.

RESEARCH ACCOMPLISHMENTS

The NASA/Fisk University Center has focused its research on one of the most promising branches of photonics—one that produces new materials or improves the production of known materials, which are the initial stage of the development of most new advanced technologies.

One research group uses recently developed nanotechnology methods to produce new materials that contain inclusions of single atoms or clusters of new atoms. These materials show surprising new properties, such as being able to change the color of light beams (which may increase the capacity of computer memories and compact disks), and to switch light beams on and off in extremely short times. This may lead to the development of optical computers, which are potentially much faster and more efficient than electronic ones. Recently, this group has contributed to resolving a long-standing controversy on how the clusters change their properties as they grow from a few atoms to their final size (published in *Physical Review*, 1996). The research of this group drew attention, which resulted in five invited talks at national laboratories and universities and drew new collaborations and financial support from two NASA Installations: Lewis Research Center (Photovoltaics) and Marshall Space Flight Center (Polymer Division).

Upconversion of near infrared light to green light in Er^{3+} doped heavy-metal-oxide glass

Graduate student Erika Thompson characterizes surfaces at the Ultra-High Vacuum Kratos spectrometer.

Another group studies new crystalline materials for the detection of light, x-rays, and gamma rays. This research includes purifying the materials, growing the crystals, determining their physical and chemical properties, and making and testing detectors. These solid-state detectors have a wide range of applications in industrial production control, military equipment, satellite studies of space and the Earth, and medical diagnostic equipment. This group was awarded a patent for a noncontact device to measure the temperature of crystals growing in a sealed glass ampoule, allowing for a better choice of growth conditions. Another patent is pending for the measurement of other growth parameters. Also, this group has delivered to Marshall Space Flight Center an original instrument for the ultra-purification of chemicals used in crystal growth. A collaboration with Goddard Space Flight Center was

started, leading to the testing of laboratory-built x-ray and gamma ray detectors in Goddard Space Flight Center balloon flights.

A third group is working with glasses and other optical materials, which could be used to make new laser sources, improve information storage technology, and develop optical sensors. Glasses have the advantage of easily being formed into whatever shape is required and, in particular, can be drawn into very thin optical fibers. Some of the glasses being studied at Fisk can be used to convert infrared light into visible light, and others are photosensitive glasses, which can be used to make fiber-optic strain, vibration, and temperature sensors. This group has produced a new glass (Erbium doped-lead-tellurium-germanate), which efficiently transforms invisible infrared to green light (usable for better disk memories), and a new crystal (Vanadium doped-cadmium-sulfer-selenide), which has the optical properties required for making compact reversible holographic memories with greater capacity than anything presently available.

Finally, a fourth group possesses the most modern equipment for studying the physical structure and chemical composition of solid surfaces. This enables measurements to be made up to the limit of locating single atoms, and to be made in environments from normal atmospheres to ultra-high vacuum. These techniques provide important information for the improvement of the fabrication processes involving solid surfaces, including the extra-thin multilayers that constitute integrated circuits. They are also useful in the determination of damage suffered by equipment components due to their use, exposure to the environment, and so forth.

Summer workshop undergraduate students, Jeffrey London and Musheraah Herd, analyze images produced by the Atomic Force Microscope.

STUDENT ACHIEVEMENTS

Fisk graduate students in physics and chemistry are performing their required master's thesis research using the state-of-the-art facilities of the Center. Fisk undergraduate students are using both the Center laboratories and a recently completed advanced undergraduate laboratory facility to perform training and research during the academic year. Undergraduate students from Fisk and other minority universities attended an 8-week, full-time intensive workshop of study and research. During the 1995–96 Academic Year, 10 undergraduates (all African Americans) and 10 graduates (8 African Americans) participated in the research activities. Four master's degrees were awarded to African American students, three of whom are continuing their education toward a Ph.D. Eighteen undergraduates (from 8 minority universities and 12 states; 8 males and 10 females) participated in the 1995 Summer Workshop. One of the Fisk undergraduates graduated in 1996, and she is now continuing her education toward a master's degree at Fisk.

Additional NASA Enterprise Area: Space Science
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Space Medicine and Life Sciences Research Center

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Date of Original Award: 1995

The objectives of the Space Medicine and Life Sciences Research Center (SMLSRC) are to: (1) develop the core infrastructure for space medicine and life sciences research; (2) develop the research capabilities and experiences in the area of space medicine and life sciences by existing faculty; (3) support the SMLSRC research efforts through the recruitment of postdoctoral research associates and additional faculty; (4) develop a student research training component and advanced graduate courses in space medicine and life sciences; and (5) develop collaborative relations with NASA, other universities, and private industry. The long-term goals for the proposed SMLSRC are to: (1) develop the Center to produce exceptionally trained minority and women scientists in space medicine and gravitational biology research and; (2) provide a criti-

cal mass of faculty and other personnel through the core program of the Center to strengthen the SMLSRC.

The SMLSRC consists of three parts. The Administrative Office will direct all SMLSRC programs and will facilitate the development of the student research training and graduate program components. The Core Program will develop the core infrastructure for gravitational biology research, provide an additional faculty, and postdoctoral research associates. The SMLSRC Research Program will provide support for the development of ground-based research to assess the mechanisms underlying the cardiovascular, musculoskeletal, and neuronal effects of microgravity. These research groups will interact through collaborative research and planned activities with other Morehouse School of Medicine units. The proposed multidisciplinary studies will be carried out using the following simulated-microgravity models: the low-shear horizontally rotating bioreactor for cellular studies; the head-down tilt hindlimb suspended rat model; and the acute/chronic bed-rest head-down tilt human model. The three research groups will use one or more of these models and thus obtain data that can be integrated and will provide a more precise understanding of the physiological responses to microgravity. These different components are complementary and will result in the SMLSRC developing into a multifaceted research center. The training component of the SMLSRC will increase the number of minority students exposed to the area of space medicine and life sciences research. The benefit to NASA is the immediate increase in minority postdoctoral level researchers involved in this important area. As the SMLSRC develops and faculty research expertise becomes established, it is anticipated that increased collaborative relationships and non-NASA support will occur.

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Center for Applied Radiation Research

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INTRODUCTION

Prairie View A&M University's Center for Applied Radiation Research (CARR) was established in 1995 to address missions and critical technologies of NASA. The mission of CARR is based on four components: research, human resource development, service, and commercialization and technology transfer. CARR conducts research in three technical areas: space environment simulation; radiation effects on electronic and photonic systems; and radiation effects on biosystems. CARR covers a range of topics for research, while focusing on the single unifying theme of radiation effects. CARR is unique in that it addresses issues from the microscopic level, truly "systems-level" materials, complex integrated circuit systems, physiological studies at the cellular level, and the human reproductive and immune systems.

RESEARCH ACCOMPLISHMENTS

Process and Radiation-Induced Defects

We have continued to improve our measurement capabilities, which will allow a better understanding of defects at the interface between silicon and silicon dioxide. The quality and integrity of this interface govern the performance of most advanced integrated circuits, including those used in space applications. The space radiation environment can damage this interface and alter the point at which an electronic device becomes active in a particular application. Recent CARR findings have led to a better understanding of two major types of radiation-induced interface defects. Acting as CARR subcontractors, research collaborators at major universities have confirmed our results by independent measurement techniques.

Single-Event Effects

High-energy particle accelerators are used to simulate cosmic rays, which cause soft (recoverable) errors in memory circuits called "single-event upsets." CARR ex-

Students of the PVAMU Center for Applied Research engaged in various Clean Room activities.

periments have confirmed theoretical predictions that bring into question the usual assumptions on the angular dependence related to how much energy a cosmic ray deposits in the materials making up a unit of computer memory. These theoretical and experimental results could influence tests for single-event effects.

Circuit Innovations
A switched capacitor, resistively hardened memory circuit has been designed and is being fabricated to reduce to practice. Circuit simulations indicate that the device is an attractive alternative to standard resistively hardened memory circuits. This circuit is currently under patent review by the Prairie View A&M Research Foundation.

Emerging Technologies
CARR has embarked on projects in new materials and quantum devices that have the potential for revolutionizing space technology. This work has attracted mainstream support and major university research collaborators. For example, the surface of the novel wide bandgap semiconductor ilmenite (a common mineral on the Moon) has been studied with scanning probe microscopy and x-ray photoelectron spectroscopy to facilitate electrical characterization of the materials. CARR is also interested in the radiation effects of future generations of quantum electronic devices that may be used in space. This work represents an excursion into a new field of scientific inquiry.

Life Sciences
CARR's work in the life sciences has identified a common endpoint that will help establish a "fingerprint" of radiation-involved damage to cells related to reproduction in culture.

RELEVANCE TO NASA STRATEGIC ENTERPRISES
Human Exploration and Development of Space/Office of Space Flight
Understanding radiation effects on materials and avionics will provide safer and more reliable operation of systems aboard the Space Shuttle, the International Space Station, and future manned spacecraft to Mars. Further, studies of the radiation effects on immune and reproductive systems help make longer duration space flights safer and more practical for both men and women.

Aeronautics and Space Transportation Technology
Avionics for future high-speed civil transports (HSCT) will need higher radiation tolerance than current avionics because of the higher operating altitude. HSCT crews will be subject to higher radiation levels than current airline crews.

Space Science
Emerging technologies will make exploring the solar system cheaper and more reliable by making deep space probes smaller and more radiation tolerant.

BENEFITS TO SOCIETY
The fast-paced trend in micro-electronics fabrication is toward smaller, more densely-packed devices. This may make even the next generation of integrated circuits susceptible to radiation from space on Earth, with the consequence that the average laptop user may experience single-event effects. Industrial research is beginning to address these issues, as well as the effects of radiation used in the processing of these chips. CARR is in an excellent position to participate in and contribute to this convergence of the needs of terrestrial and space technology.

STUDENT ACHIEVEMENTS
CARR has supported 10 graduate and 23 undergraduate students during this time, and several of these students have graduated and gone on to graduate study or employment in the avionics or commercial electronics industry. Additionally, we have extended learning enrichment opportunities at the high school level through an Explorer Post and by extending internships to minority students and faculty.

Additional NASA Enterprise Areas: Aeronautics and Space Transportation Technology; Space Science
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Tuskegee University NASA Center for Food Production, Processing and Waste Management in Controlled Ecological Support Systems (TUNACC)

Director: Dr. Walter A. Hill
Tuskegee University
Tuskegee, AL 36088
Date of Original Award: 1992

INTRODUCTION
The overall goal of the TUNACC has been to provide sweetpotato and peanut information and technologies and student training applicable to bioregenerative food production systems for life support on long-term manned space

Dr. Desmond Mortley, Crop Production and Environmental Systems team leader and graduate student Kendra Stanciel, display a channel of peanuts taken from a growth chamber for harvest. Technician Doris Douglas is shown at the chamber door.

missions. The research responsibilities required to achieve this goal have been divided among several research units, five of which are highlighted below. Student trainees are an integral part of the research.

RESEARCH ACCOMPLISHMENTS

The Growing Systems and Environmental Factors Unit has been concentrating on determining the best systems and environmental conditions for growing sweetpotatoes and peanuts hydroponically for space missions. During 1996, Kennedy Space Center (KSC) suggested that we compare the growth of sweetpotatoes using their fan-shaped growing trays and protocol with the rectangular channels and protocol used at Tuskegee University. Preliminary results indicated that production within the KSC system results in a preponderance of sweetpotato foliage over storage roots, with the opposite occurring using the Tuskegee University system. The nutrient solution compositions appear causative. While leaves are nutritious and edible, only very limited amounts can be accommodated in space. Other studies were carried out with peanuts to determine the best conditions for their growth. When peanuts were grown under conditions of elevated carbon dioxide (CO_2)—a condition of closed systems in space—it was found that the growth of seeds, pods, leaves, and roots in three peanut cultivars was enhanced by increasing CO_2 levels from 400 (ambient) to 700 mmol mol^{-1}.

The Germplasm Development Research Unit aims to improve sweetpotato and peanut crops through biotechnology. In 1996, this unit confirmed that some of the transgenic sweetpotato lines they developed showed protein increases of three-to five-fold over the control.

The Nutrition and Food Processing Research Unit is working on the processing of the edible parts of peanuts

Tuskegee graduate Jada Jackson, who received her B.S. in biology in May 1996, explains to Tuskegee University computer systems analyst Jill Hill the workings of one of the CO_2 units in a study of "Growth Characteristics of Florida Scrub Vegetation as Affected by a Three-Month Exposure to Elevated CO_2." Jada's work was conducted on Kennedy Space Center land under the supervision of Dr. Burt Drake of the Smithsonian Institute; Jada is presently pursuing a master's degree in forest ecology at the University of Minnesota.

Carla Wilson, Tuskegee University graduate student in food and nutritional science, prepares a meal, including peanut-topped chicken, candied sweetpotato, sweetpotato leaf greens, vegetable stir-fry with sweetpotato, on the occasion of a site visit by a NASA review team. Carla was an intern at Johnson Space Center during the summer of 1995.

and sweetpotatoes into a variety of nutritious and palatable foods. Much has been done with sweetpotato products in the past, and last year one company expressed interest in commercializing our sweetpotato beverage. This resulted from a 1996 summer fellowship awarded to our product development specialist by the U.S. Department of Agriculture, which focused on the product commercialization process. During 1996, this unit concentrated on developing new peanut products and recipes. The goal here is to provide tasty, nutritional, and varied foods for future space workers, with commercial spinoffs a secondary benefit.

The Waste Management and Recycling Unit showed in 1996 that nutrients in the inedible parts of sweetpotatoes can be recovered and recycled in a replenishment protocol for further sweetpotato production.

Finally, the Plant Modeling Unit collects data and recommends experiments for the purpose of retrieving additional needed information on growing sweetpotatoes and peanuts in controlled environments. A hypothesis that this unit developed in 1996 relates starch storage in sweetpotatoes to storage root initiation. If this hypothesis proves to be true—and experiments are under way to test it—it will be important not only to food production in space, but also to sweetpotato producers on Earth, particularly in areas of expected food shortages.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

The applicability of our research to NASA Strategic Enterprises is vast, and the potential benefits include:

- ♦Studies conducted under the Growing Systems and Environmental Factors Unit represent a refinement of the information required for testing these crops in bioregenerative facilities of the advanced life-support system development program at Johnson Space Center (JSC) and KSC, in preparation for the Human Exploration and Development of Space Enterprise.
- ♦The increases in protein achieved by the Germplasm Development Research Unit (if they can be duplicated in varieties adaptable to controlled environments), in terms of compactness, dry weight, overall nutritional content, and taste, would advance life-support objectives.
- ♦The aspects of waste recovery and recycling being investigated by the Waste Management and Recycling Unit must necessarily be integrated into a flawless bioregenerative life-support system to enable a sustained human presence in space.
- ♦The research conducted by our Plant Modeling Unit, as discussed above, could prove to be very useful to food production in space.

BENEFITS TO SOCIETY

The research being performed by the Germplasm Development Research Unit holds promise for populations suffering protein deficiency. Likewise, the research being conducted by our Plant Modeling Unit (as previously stated) could be useful to sweetpotato producers on Earth, particularly in areas of expected food shortages.

STUDENT ACHIEVEMENTS

In addition to student involvement in the above Tuskegee/NASA research tasks, five Tuskegee University students served internships at the Johnson and Kennedy Space Centers.

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Mission to Planet Earth

Center for Hydrology, Soil Climatology and Remote Sensing

Director: Dr. Tommy L. Coleman
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Date of Original Award: 1995

INTRODUCTION

The initial research thrust of the Center for Hydrology, Soil Climatology and Remote Sensing (HSCaRS) is to develop a comprehensive research program investigating hydrologic processes, with emphasis on remote-sensing measurements and modeling of soil moisture. The objectives are threefold: first, to develop a measurement/modeling strategy from low-resolution microwave data to derive soil moisture profile information and to determine its variability on a range of spatial scales; second, to develop a precise, inexpensive, *in situ* technique for measuring soil moisture to facilitate ground truth of remotely sensed data and validation of global and regional climate change models; and third, to take knowledge from hydrologic modeling, coupled with evolutionary computing techniques, to model and visualize soil moisture, soil erosion, and contaminant transport through soils and within water bodies.

RESEARCH ACCOMPLISHMENTS

Our research efforts are grouped into four major areas: Hydrology/Hydrologic Modeling (H/HM); Remote Sensing/GIS (RS/GIS); Sensor Development (SD); and Evolutionary Computing (EC). Several projects were initiated under these subject areas during 1996, which produced a number of publications and presentations.

Hydrology/Hydrologic Modeling (H/HM)

The most significant research accomplishment this year was the establishment of a research testbed at Alabama A&M University's Winfred Thomas Agricultural Research Station, near Hazel Green, Alabama. The testbed consists of four 50 by 60 m plots, instrumented with state-of-the-art hydrologic and microwave remote-sensing devices to measure surface and subsurface soil moisture. The scientific objectives focused on defining the soil depth, emitting and reflecting energy at various microwave wavelengths, characterizing temporal and spatial variability of surface moisture, and measuring soil moisture at different frequencies.

The remote-sensing measurements from the field experiments were supported by soil profile instruments that measured temperature fluxes, current soil moisture, gravimetric soil moisture measurements, and a detailed soil and vegetation characterization within the testbed. This field experiment will be repeated during August 1997.

Sensor Development (SD)

Scientists are investigating the feasibility of developing a portable soil moisture measuring device that is inexpensive, accurate to within ±1%, and easy to use. Three approaches are being followed: nontraditional materials; infrared reflectance and Raman scattering; and optical reflectance techniques. Devices from each approach have been fabricated and tested in the laboratory and will be deployed under field conditions during the Huntsville '97 field experiments.

Evolutionary Computing (EC)

This research area focuses on the creation of algorithms that will enable one to predict both the forward and inverse behavior of the soil moisture problem. Using simulated data that contained variables for elevation, soil type, evapotranspiration rates, rainfall, transport, and noise, an associative memory was developed to predict moisture samples. This model is better known as the Fast Analog Associative Memory (FAAM). From the data generated, a leveling of the measure was apparent. The absolute level was slightly higher for cases with noise, but still tended to level, indicating that this particular problem is solvable. This method will be tested on real-world data from the Huntsville '96 and '97 field experiments.

Remote Sensing/GIS (RS/GIS)

This research area focuses on the use of basic and advanced automated image-processing techniques to assess surface vegetation, soil, and water conditions of the Earth's surface. Current research involves an assessment of vegetation characteristics associated with land cover type as a component of the hydrology of the Middle Coosa River in northeastern Alabama. Quantitative data has been collected at 85 sites throughout three subwatersheds of the study area. Vegetation data were summarized by four characteristics: relative abundance; relative dominance; relative frequency; and importance value. These indices will be compared with vegetation classifications obtained from Thematic Mapping (TM) imagery captured during the summer of 1995.

Educational Outreach (EO)

We have established an educational outreach component of HSCaRS to address the need for increasing the number of disadvataged and underrepresented minorities who are U.S. citizens with advanced degrees in NASA-related fields. We have initiated an undergraduate Summer Enrichment Program (SEP), which began during the summer of 1996. The program is designed to provide undergraduate students in NASA-related fields an opportunity to participate in meaningful research tasks that contribute to NASA and HSCaRS research missions.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

The research and educational outreach activities of HSCaRS are well grounded in the Strategic Plan of NASA's Mission to Planet Earth (MTPE). The overall goals of HSCaRS fit within three of the stated goals of MTPE, whose purpose is to increase understanding of the Earth as an integrated system, observe and characterize the Earth system using satellite aircraft and associated research systems, and characterize and understand natural and human-induced change on global and regional scales with emphasis on climate change.

According to the document, under long-term measurements for global change research, MTPE is committed to providing a specific series of 24 prioritized scientific measurement areas for a 15-year term. The research occurring in HSCaRS falls within six of these areas—four under the broad heading of land measurements, and two under the heading of atmosphere.

The research and outreach activities of HSCaRS are also relevant to two of the revised goals of MTPE, which are

to "expand scientific knowledge of the Earth system using the unique vantage point of space" and "disseminate information about the Earth system."

BENEFITS TO SOCIETY

It is our belief that the research activities being conducted in HSCaRS will enable the average citizen to better understand hydrology and the role of soil moisture in our ecological system.

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Research Center for Optical Physics

Director: Dr. Doyle Temple
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Hampton, Virginia 23668
Date of Original Award: 1992

INTRODUCTION

The mission of the Research Center for Optical Physics (RCOP) is to promote world-class leadership in selected areas of optical sciences and technologies and to develop underutilized human resources to meet the Nation's science and engineering labor needs in the 21st century. The vision of the RCOP is to establish Hampton University as a premier institution for optical scientific advancement and education in the mid-Atlantic United States. There are three areas of research that form the core of the RCOP's strategic focus:

- Atmospheric Sciences and Optical Remote Sensing Technology
- Optical Materials (including laser, nonlinear optical, and smart materials development)
- Non-Intrusive Diagnostics

Krista Lee is setting up the data acquisition system for a

RESEARCH ACCOMPLISHMENTS

During the past year, RCOP researchers have developed a variety of new technologies and have made a number of significant scientific discoveries. In the area of Atmospheric Sciences and Optical Remote Sensing Technology, RCOP researchers have developed new laser light sources that are being used to study ozone molecules in the upper atmosphere, a new tunable infrared laser for use in the measurement of greenhouse gases for the study of global warming, and new laser technology used to assist NASA scientists in their study of aircraft wake vortices, a major factor in airline safety.

In the area of Optical Materials, the RCOP has developed a new patented method of calibrating fiber-optic sensors for use in monitoring structures such as bridges or airplane wing surfaces; made discoveries about the physical properties of new holographic data storage materials that have the potential to dramatically increase data storage capacity above that of CD–ROMs; successfully fabricated new organic thin films for use as low-current LEDs, thresholdless laser devices, and photonic band gap materials; and developed new technology for the testing of mid-infrared laser materials for use in eye-safe lasers for remote sensing.

In the area of Non-Intrusive Spectroscopy, the RCOP has developed new technology to detail the flow analysis of the High-speed Flow Generator (HFG) at NASA's Langley Research Center (LaRC) for use in aerodynamic measurements, new techniques to measure the flow velocity at the nozzle exit of the Solar Thermal-Electric Propulsion (STEP) systems for use in low- to high-orbital transfer vehicles and a new, very-high-sensitivity, focusing Schlieren system for a fast-flow visualization of low-density flow fields.

The RCOP has also established numerous research and educational collaborations with private industries, NASA and other government agencies, and universities. Some of

these include: Brimrose Corporation of America; Deltronic Crystal Industries, Inc.; Spire Corporation; Hughes Research Laboratories; Northrop-Grumman; NASA LaRC; NASA Lewis Research Center; Clark Atlanta University; the University of Virginia; Florida A&M University; the University of Rochester; the University of Hamburg; Fisk University; Norfolk State University; the University of Florida; California State University, Sacramento; Virginia Polytechnic Institute; Virginia State University; and the AF Loffe Physicotechnical Institute of the Academy of Sciences in St. Petersburg, Russia.

This year, the RCOP has completed development of six state-of-the-art research laboratories:

- The Optical Remote Sensing Technology Laboratory is developing: lasers for lidar remote sensing of the atmosphere (especially those of significant value to NASA); field measurements with lidar systems interpretation of lidar data in conjunction with other atmospheric data to understand atmospheric chemistry and physics; and laser diagnostic techniques for other applications.
- The Ultra-Fast Laser Spectroscopy Laboratory has developed a state-of-the-art wave-mixing spectroscopy laboratory for the study of nonlinear properties of new materials, such as single-crystal oxides, polymers, organic thin films, and multiple quantum well devices.
- The Organic Thin Film Laboratory has developed the technology for fabricating of organic thin film devices for use as low-current LEDs, thresholdless laser devices, and photonic band gap materials.
- The Fiber-Optic Sensors and Smart Materials Laboratory is fabricating discrete stress, strain, temperature, and acoustic fiber-optic sensors along with their readout interfaces for NASA-oriented uses. Also under development in this lab are high-definition distributed Bragg grating fiber-optic sensors, as well as systems that can address the particular needs of NASA's Mission to Planet Earth.
- The Laser Materials Development Laboratory and the Non-Intrusive Diagnostics Laboratory have established a high-resolution spectroscopy facility that allows for the complete visualization of aerodynamic flows, developed an advanced global flow visualization system, and developed new optical diagnostic techniques to allow for the detailed analysis of the flows for validating models of physical and chemical processes in aerothermodynamics and propulsion research.

Eric Brass is conducting experiments in holograpgy.

STUDENT ACHIEVEMENTS

During the past year, 41 students participated in RCOP research and education programs, including 2 African American high school students, 19 African American undergraduate students, and 16 African American graduate students. The center produced 4 students with bachelor's degrees and 1 student with a master's degree. Also, 3 students passed the doctoral qualifying examination in Physics, bringing the total number of doctoral candidates to 10, 7 of whom are African Americans.

The Center also hosted several very successful outreach programs. These included: the Summer Physics Institute (SPI), a 6-week program in optics for undergraduate students; the Undergraduate Institute in Physics (UnIPhy), which was a research training program for undergraduate students; a Summer Science Training Institute for middle and high school science teachers; a workshop for middle and high school guidance counselors; mentorship and tutoring programs in the local area schools; and the coor-

dination of numerous science demonstrations by RCOP faculty for local schools. A host of other outreach and recruiting activities were undertaken by RCOP faculty and students in the local area elementary, middle, and high schools.

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Center for the Study of Terrestrial and Extraterrestrial Atmospheres

Director: Dr. Arthur N. Thorpe
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Washington, DC 20059
Date of Original Award: 1992

INTRODUCTION

The strategic focus of the Center for the Study of Terrestrial and Extraterrestrial Atmospheres (CSTEA) is to establish at Howard University a self-supporting, world-class facility for the study of terrestrial and extraterrestrial atmospheres, with special emphasis on the training of disadvantaged underrepresented minorities in aerospace-based sciences and engineering. To this end, CSTEA has implemented the Howard University Program in Atmospheric Science (HUPAS), a new graduate degree program in atmospheric sciences. This program offers courses in atmospheric chemistry, physical meteorology, geophysical fluid dynamics, air pollution, and a variety of other related topics. There is also a "Current Topics in Atmospheric Sciences Seminar," which features weekly speakers from Goddard Space Flight Center's Laboratory for Atmospheres.

RESEARCH ACCOMPLISHMENTS

CSTEA researchers and students continue to be involved in the acquisition and analysis of data from instruments aboard NASA's EOS satellites. ATMOS/ATLAS I measurements of thermospheric and mesospheric nitrogen oxide (NO) have been analyzed, to understand NO production and its sensitivity to solar variations in the upper atmosphere. The results of these studies indicated that the discrepancies in the measurements worsen with photochemical models at low latitudes.

In another study, a combination of satellite data from the Special Sensor Microwave/Imager (SSM/I) and Mesoscale Model Simulation have been used to explain the Southern Hemisphere's tropical ozone maximum. The results of these studies indicate a significant role of lightning and vertical transport associated with deep convective systems in the transport of pollutants from biomass fires in continental Africa to the South Atlantic.

Experimental and theoretical studies of the chemistry in the atmosphere of Titan have also been performed. Laboratory techniques involving laser spectroscopy and mass spectral analysis have been used to measure photoabsorption cross sections and the kinetics of cyanoacetylenes and their reactions. Quantum chemical calculations have been used to explore the structures and energetics of these reactions. Through these studies, we have gained a deeper understanding of the photochemistry and evolution of this primitive atmosphere.

One of the major efforts at CSTEA involves the design and development of a Quartz Crystal Microbalance (QCM) instrument and chemical coatings that are sensitive to select trace gases. This instrument has the capability of simultaneously measuring both minute aerosol particles and low-concentration gases in various regions of the atmosphere. The QCM instrument uses the change in the frequency of a vibrating quartz crystal to measure the mass of either particulates or gases that have attached to its surface. Thin chemical films are being developed with specific sensitivity to various chemical compounds, such as ammonia, ozone, sulfur dioxide, organo-phosphorous compounds, nitrogen oxides, nitric acid, and even the vapors of explosives. Measurement of the concentrations and spatial distributions of many of these compounds are important for assessing the environmental impacts of aircraft and industrial emissions. The development of the QCM instrument has allowed detection sensitivity down to 1 ng/cm^3.

In another part of the research at CSTEA, we are developing microbalances with silicon carbide and other wide-bandgap semiconductor materials. These materials, because of their unique physical properties, should increase the sensitivity of these detectors to at least 0.1 ng/cm^3. The development of the QCM instrument supports NASA's efforts to understand the complex chemistry of the lower atmosphere by providing a simple and acoustic measurement method.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

The research program of the Center is focused primarily on the terrestrial atmosphere, and consequently the lead Strategic Enterprise for this University Research Center (URC) is the Mission to Planet Earth (MTPE). The cor-

nerstone of MTPE is Earth Observing System (EOS). Other research projects at CSTEA involve studies related to Aeronautics and Space Transportation Technology and to Space Sciences.

BENEFITS TO SOCIETY

The benefits of CSTEA research to the average citizen come from the enhanced ability to monitor and predict chemical and physical changes in our environment. An additional benefit is the alternative uses of the QCM instrument. This device and its associated chemical sensors can potentially be used for detecting of chemical leaks, hazardous materials, and even airborne viruses; the instrument is sensitive enough to do so before lethal levels of exposure are reached.

STUDENT ACHIEVEMENTS

One of CSTEA's top priorities is the training of disadvantaged and underrepresented minorities in the space sciences. To this end, CSTEA had 30 undergraduate and 25 graduate students involved in research over this reporting period. All CSTEA students major in the fields of Chemistry, Engineering, or Physics. All students —both undergraduate and graduate—report to the Principal Investigators on a daily basis for research work assignments in the individual laboratories. Some of their achievements are as follows: 19 student presentations have been made at conferences; 6 students have co-authored journal articles; 3 students have received their B.S. degrees; 4 students have received their M.S. degrees; 3 students have received their Ph.D.'s; 2 graduates are now employed in NASA-related fields; and 27 students participated in SIRTAS (Summer Institute and Research Traineeship in Atmospheric Sciences) in 1995.

Additional NASA Enterprise Areas: Aeronautics and Space Transportation Technology, and Space Science

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Tropical Center for Earth and Space Studies

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Date of Original Award: 1995

INTRODUCTION

The Tropical Center for Earth and Space Studies (TCESS) comprises a multidisciplinary effort in several areas: UV Radiation Effects; Crustal Deformations of the Lesser Antillean Arc; Advanced Automated Image Analysis; Semiconductor Materials and Electronics for Space Applications; the Space Information Laboratory; and a small Education and Outreach effort.

RESEARCH ACCOMPLISHMENTS

Space Information Laboratory (SIL)

This component is charged with receiving data from satellites and making it available to the user components within TCESS. In December 1996, we installed an High Resolution Picture Transmission (HRPT) receiving station for the National Oceanic and Atmospheric Administration (NOAA) satellites that have Seaview Wide Field-of-view Sensor (SEAWiFS) capability. An antenna capable of receiving Synthetic Aperture Radar (SAR) and LANDSAT 7 data will be installed and commissioned during 1997. The SIL has also contracted with The Johns Hopkins University's Ultraviolet Spectroscopic Explorer project and will serve as the Primary Ground Station for receiving and tasking the satellite.

The UV Radiation Effects

Researchers are currently studying the effect of ultraviolet radiation on tropical marine organisms.

Crustal Deformations of the Lesser Antillean Arc

Research is focused on the interaction of the Caribbean and North American plates along the Lesser Antilles island arc, a series of islands composed of 14 active or potentially active volcanic centers. The last two field campaigns and initial data processing have now been completed. We have concentrated our efforts for the first year and a half of our NASA project on the ongoing eruption of the Soufriere Hills volcano in Montserrat, British West Indies, which began on July 18, 1995, and continues today. Our results so far have shown that GPS geodesy can be used

Dr. Allan Smith sits with the GPS station at La Souffriere volcano, visible in the background.

for cost-effective and timely hazards assessment of explosive island arc volcanoes and that the observed surface deformation is consistent with an elastic response of the volcanic edifice as indicated by numerical models. It has also been found that previously unrecognized eruptions occur in the Soufriere Hills stratigraphic record, that observed pyroelastic flows at Montserrat were largely the result of gravitational dome collapse (whose flow paths can be modeled quantitatively), and that the regional tectonic network framework exerts strong controls on the eruptive style and dynamics. The preliminary results have been presented at three conferences.

Advanced Automated Image Analysis
This group's research is focused on the development of algorithms for signal-and image-processing applications of remotely-sensed data. Accomplishments for this year include the development of several algorithms for image compression using fractal and fuzzy logic methodologies. Wavelet and fractal-based algorithms have been developed for texture analysis/image segmentation, showing superior

Xana Conelly works at a Computer-Driven Analyzer.

performance over the spatial gray level dependence method and Gabor transform for texture analysis. Research in the development of efficient algorithms for interferometry using SAR data has been started, and a preliminary version of a computational signal-processing environment for such applications has been developed. In the area of inverse problems in remote sensing, we have developed and tested (with simulated data algorithms) for temperature retrievals from microwave radiometry based on regularization methods, with results showing the ability to determine the fine structure of the profile—something that has not been observed with other retrieval algorithms. An initial prototype of a World Wide Web tool to disseminate the algorithms developed in this research was finished. Twenty papers were published at conference proceedings, and three were published in peer-reviewed journals.

The Semiconductor Materials and Electronics for Space Applications (SMESA)
This group within TCESS consists of 7 scientists and engineers and 16 students. A salient finding by researchers in this group was the very recent discovery of an irradiation-induced luminescence enhancement effect in nanostructured materials. A dramatic enhancement of luminescence intensity and decay time was observed for these materials after irradiation with ultraviolet laser light. A physical mechanism explaining the effect was also proposed. Another recent development led to new persistent phosphors, with brightness of 10 times stronger than that of traditional phosphors and persistence time of up to 18 hours. Power-processing electronics working at low temperatures are also being developed as part of the work of the SMESA group. DC-to-DC converters have been built and tested at temperatures down to that of liquid nitrogen. Conversion efficiencies close to 90 percent have been demonstrated.

RELEVANCE TO NASA STRATEGIC ENTERPRISES
Some of the materials under development by the SMESA group could be of interest for high-sensitivity light detectors and for the development of new lasers. Other materials will be useful for infrared beam finders, image storage technology, and night-vision devices. The low-temperature electronics under investigation by this group will help minimize spacecraft launch weight and bulk by reducing the need for radioisotope thermoelectric generators and heating units, which are currently used to keep electronics warm in deep space. These low-temperature electronics may also be useful in other very cold environments. Additionally, the SIL will make our satellite ground station facilities available for other NASA-sponsored projects that may require them.

BENEFITS TO SOCIETY
The results from our studies on volcanoes can be used for cost-effective and timely hazards assessment of explosive island arc volcanoes. Further, the Education and Outreach component has developed the "Science on Wheels Program," which brings science demonstration shows to teachers and K–12 students. During this past year, it also joined the NASA GLOBE program to enhance its offerings.

STUDENT ACHIEVEMENTS
The UV Radiation Effects component now has four (two M.S. and two Ph.D.) students doing their thesis work on the effects of ultraviolet radiation on tropical marine or-

ganisms. Three papers have been submitted by the students for publication in peer-reviewed journals. Three additional papers will be presented by two of the students and the Principal Investigator at the Aquatic Sciences Meeting of the American Society of Limnology and Oceanography (ASLO) that will take place in Santa Fe, New Mexico, during February 1997. The students will participate in the ASLO program for underrepresented minorities in limnology and oceanography, and they will also attend special sessions, including one on UV Effects in Freshwater and Marine Systems. The group also participated in the NASA University Research Center's Technical Conference held in Albuquerque, New Mexico, following the ASLO Conference.

During FY 1997, the Advanced Automated Image Analysis Component had 9 undergraduate students and 5 graduate students participating in the project. Also, 13 student presentations were given at both the local and national level.

The University of Puerto Rico at Maygüez research team includes two graduate students and three undergraduate students from the Department of Geology. The last two field campaigns and the initial data processing have been completed by our two graduate students.

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Pan American Center for Earth and Environmental Studies

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Date of Original Award: 1995

INTRODUCTION

The Pan American Center for Earth and Environmental Studies (PACES) has the dual goals of contributing research to support NASA's Mission to Planet Earth Strategic Enterprise and contributing to the education of the next generation of scientists and engineers, many of whom will be ethnic minorities. PACES has established a major database of remote-sensing, geophysical and geological, and environmental information generated by NASA and other agencies for a region comprising the southwestern United States and northern Mexico. This region is presently experiencing significant aspects of global change, and the data being assembled at PACES are used to support pure and applied research and policy decisions. Specifically, PACES supports research and applications in three major areas: geoscience; environmental science and engineering; and computer science and engineering.

RESEARCH ACCOMPLISHMENTS

Geoscience faculty and students at PACES have initiated an integrated effort to look at the basinal structure, water resources, and tectonic setting of the southern Rio Grande rift. This area spans the region from central New Mexico to the southern part of the state of Chihuahua, Mexico. As part of this effort, PACES is conducting geological studies of: the NASA test facility near Las Cruces, New Mexico; the El Paso-Juarez region; the Indos Mountains region; the Sierra Pena Blanca region; the Ciudad Chihuahua region; and the Rio Conchos drainage region. In an area where water is a scarce commodity, PACES researchers are actively engaged in studies that utilize gravity maps, topographic maps, and satellite images to gain a deeper understanding of the current capacity of water resources. Remotely sensed satellite imagery is being studied to determine models to describe the extent of urban change for the El Paso-Juarez area and other metropolitan areas. Additionally, PACES is investigating the effects on crops irrigated by Aguas Negras in the area of Ciudad Chihuahua, Mexico.

PACES conducts geoscience research in a region extending from the Sierra Nevadas across Death Valley to Lake Mead and onto the Colorado Plateau. This very complex region is of great scientific interest, because it has extended by over 100 percent in the last 40 million years. The Death Valley area is of great interest to collaborators of PACES at JPL, and a comprehensive mosaic which crosses this area has been prepared and a digital terrain model constructed. Additionally, geoscience researchers are focusing on the area around the Valles Caldera, on whose slopes rest the Los Alamos National Laboratory. Here, PACES is working with Los Alamos colleagues to understand the evolution of this volcano and the risk it poses to the Laboratory.

A memorandum of understanding is under review that links PACES, NASA's Mission to Planet Earth, the Earth Data Analysis Center of the University of New Mexico, Instituto Technologico de Estudios Superiores de Monterrey, and the Transboundary Resource Inventory Program (TRIP). This is an effort to better understand the distribution and composition of haze in the lower troposphere of the Texas/Mexico border region. It will

include the analysis of historical satellite and aircraft imagery, as well as utilization of data from the recently launched NASA satellite with capabilities for measuring aerosols and particulates in the troposphere. The objective is to determine the sources and meteorological conditions that promote the development and control of the distribution of haze, as well as to document its historical development in the border region of Texas.

Working with the same consortium of organizations, and in cooperation with the North American Commission on Environmental Cooperation, PACES is participating in the development of a border-area regional airshed model, which will be used as the pilot project for a continental airshed model. The emphasis in this modeling effort is on the transpiration and dispersion of health-related atmospheric pollutants on a continental scale.

Many agencies acquire, store, and process geographically based and imaged-based data, which are typically acquired through remote sensing. There are two major problems that arise in making data of this type readily available to potential users. The first problem is that it takes a significant effort to do the exploratory programming to extract data of interest from the raw data. Also, once the data have been processed and are residing in a processed-data database, it takes too long to do further processing in a database host language. The second problem is that it is often difficult to know how high-level tools used to manipulate the data will interact. In other words, there is no known formal specification language available to describe the functionality of the various tools that comprise the software architecture. Computer science researchers at PACES are involved in studying and solving these problems. Along these lines, work has been completed on the semantics of SequenceL, a high-level language that can be used as a platform for many of the tasks associated with the processing of geographically based and image-based data. Efforts to commercialize SequenceL are being funded by the IBEX Corporation. Additionally, work has begun on a Boolean algebra root language for expressing database integrity constraints.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

PACES is aligned with NASA's Mission to Planet Earth, and alliances have also been formed with NASA's Goddard Space Flight Center, NASA's Ames Research Center, and the Jet Propulsion Laboratory. El Paso is ideally situated as a center for Earth and environmental studies in southwestern North America. Much emphasis has been placed on the initiation of research projects that are of importance to the U.S./Mexico border region and the Rio Grande Corridor, which is a geographical area being subjected to significant levels of environmental stress. These projects are such that they can be studied using remotely sensed imagery provided from current and future NASA satellites.

The computer science research efforts at PACES are directed toward the development of software architectures that will facilitate the transfer of remotely sensed and geographically based data into the hands of users such as policy and decision makers.

BENEFITS TO SOCIETY

Research efforts in both geosciences and environmental science and engineering have broad implications on improving the life of citizens of both the United States and Mexico. All of the Center's region of interest is at least semi-arid, and much of it would formally be classified as arid. As a consequence, considerable attention has been focused on research relating to water resources. New initiatives are also being directed toward modeling the dispersion of health-related atmospheric pollutants that often cross international and state boundaries. Urban development, grazing, mineral and ground water mining, farming, and deforestation caused by natural processes and logging have all had significant effects in the region. Remotely sensed data from satellites are a powerful means to assess the impact of these factors, and remote sensing provides a natural framework for the study of problems shared by multiple states and countries.

STUDENT ACHIEVEMENTS

During its first year of operation, PACES provided financial support for nine undergraduates, ten master's students, and six doctoral students in its research activities. Another 45 students received training in remote sensing and geographical information systems through courses recently developed and taught at the University.

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Space Science

Center for Automated Space Science

Director: Dr. Michael R. Busby
Tennessee State University
Nashville, TN 37203-3401
Date of Original Award: 1995

INTRODUCTION

The objective of the Center of Automated Space Science (CASS) at Tennessee State University (TSU) is to achieve a broad-based aerospace research capability that will foster new science and technology concepts for autonomous space systems, expand the Nation's base for aerospace research and development, develop methods for increased participation by faculty and students at TSU and its partners at Western Kentucky University and South Carolina State University, and increase the number of disadvantaged and underrepresented minorities who are U.S. citizens with advanced degrees in NASA-related fields.

RESEARCH ACCOMPLISHMENTS

During its first year, CASS researchers produced 35 publications that communicated their findings to the scientific community. Research highlights for year one are presented below.

Automated Astronomy Group

TSU began construction of its 2-m automatic spectroscopic telescope (AST) as the flagship instrument of a completely automated observatory. CASS astronomers located a site for the AST at Washington Camp, Arizona, which is owned by Fairborn Observatory, the on-site manager of the TSU automatic photometric telescopes (APTs). TSU researchers decided to build the telescope and dedicated spectrograph in Tennessee. The basic properties of both the telescope and spectrograph were determined, a 2-m primary mirror was purchased, and a contract was awarded for the secondary mirror.

After a rather lengthy period of debugging, the new TSU 32-inch APT began making routine, high-precision observations of solar duplicate stars in the spring of 1996. Our four APTs collected 32,352 group observations of semi-regular pulsars, chromospherically active (CA) stars, lower-main-sequence stars, and solar duplicates. For the first time, one of our APTs was successfully controlled via the Internet in near real time by a prototype artificial-intelligence scheduler running on a remote computer at NASA's Ames Research Center. An analysis of the 30-inch and 32-inch APT observations of solar-type stars demonstrated a precision of roughly 0.0002 magnitude in the seasonal means, sufficient to track solar luminosity cycles. The results of a major automated search with the 16-inch APT for low-amplitude photometric variability in new CA stars were published (*Astronomical Journal*, **110**, 2926, 1995). Forty-one new variable CA stars were discovered, and their properties were discussed in this paper. Important new insights into the photometric behavior of CA stars were also published (*Astrophysical Journal*, **462**, 888, 1996). A paper was submitted (*Astrophysical Journal*, **474**, 503, 1997) on the properties of several old, solar-type stars recently discovered to exhibit radial-velocity variations that implied the existence of planetary mass companions. Our observations proved crucial to confirming the existence of these new planets by eliminating alternative explanations to the radial-velocity variations (such as pulsations, starspots, or convective motions). A careful search for transits of the companion to 51 Pegasi was not successful, but nevertheless, demonstrated a precision sufficient to discover transits of Earth-size planets around old, solar-type stars under favorable circumstances.

Advanced Control Systems Group

Researchers have developed a new approach to detect structural damage to flexible structures by measuring the changes of transfer function parameters. While our computer simulation has yielded promising results for simple models, we are currently expanding this approach to more complex cases.

A portion of the TSU MATLAB Robust Control Toolbox has been placed in the public domain to test its demand as well as its design and analysis of real-world problems.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

CASS accomplishments support specific needs in two of NASA's Enterprises: Space Science and Mission to Planet Earth. Specifically, the completion and operation of a completely automated astronomical observatory will be utilized for obtaining ancillary and/or backup observations made with NASA satellite observatories. The CASS research results relating to the confirmation of the existence of extra-solar planets is relevant to the Origins program in the Office of Space Science. Also, a better understanding of Sun-climate links will be obtained from luminosity-cycle APT data of solar-type stars, which is one of the goals of the MTPE Enterprise.

BENEFITS TO SOCIETY

The origin and distribution of life in the universe have intrigued civilizations since earliest times. The question, "Are we alone?" continues to fascinate the average citizen. CASS's role in the search for other solar systems will play a role in seeking the answer to this question. Global

environmental change affects all humans, whether the primary driver has anthropogenic or solar origins. The CASS research on luminosity cycles in solar duplicates will aid in determining the relative importance of each of these possible climate drivers.

STUDENT ACHIEVEMENTS

During year one, 51 students (48 undergraduate and 3 graduate) participated in the CASS program. Eight students attended and four presented papers at the First National Student Conference sponsored by NANURC at North Carolina A&T University.

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INSTITUTIONAL RESEARCH AWARDS

The purpose of the Institutional Research Awards (IRA) program is to strengthen the capacity of minority institutions to provide a quality learning and research environment for students traditionally underrepresented in science and engineering fields and to increase their opportunities to participate in and benefit from NASA and federal research and education programs. Through IRA funding, minority institutions and researchers are given the opportunity to enhance their research and educational capabilities in NASA-related fields, providing the additional benefit of increasing their ability to enter the mainstream competitive research process.

Now in its 3rd year, the IRA program funds are enhancing research and education capabilities at five Hispanic-Serving Institutions. This report summarizes the activities of these IRA's during the summer of 1995 and academic year 1995–1996 reporting period. During this period, 60 professional-level investigators were involved in research projects at the IRA's, including 37 faculty members, 18 research associates, and, 5 postdoctoral fellows. A total of 113 students—including 64 undergraduates and 49 graduate students—participated in these research activities. The research accomplishments were documented in 40 refereed papers or book chapters published during this time period. Significantly, 26 students were authors or co-authors of these publications. An additional 18 papers or book chapters, including 21 student authors or co-authors, were accepted for publication during this period. The broader research community was informed of this work through 55 technical presentations given at national and international conferences, including 21 presentations given by students.

During the reporting period, the five developing IRA's were able to leverage their NASA MUREP expenditures ($1,964,184, not including $579,454 of student support) to an additional $2,274,999 in research support, $796,800 from other NASA programs, and $1,528,199 from other agencies.

A major goal of the IRA program is to increase the number of underrepresented minorities and students with disabilities receiving advanced degrees and entering careers in NASA-related fields. Sixty-four of the 113 students (57 percent) participated at the bachelor's-degree level; 31 out of 113 (27 percent) participated at the master's-degree level; and 18 out of 113 (16 percent) participated at the doctoral-degree level. Eighty-two percent of the participating students were members of an underrepresented ethnic minority group.

Thirty-one of the student participants obtained degrees during FY 1996: 22 bachelor's degrees; 7 master's degrees; and 2 doctoral degrees. Eighty-two percent of the graduates were members of an underrepresented ethnic minority group. Eight of the graduates were employed in NASA-related fields: four bachelor's-degree graduates and four master's-degree graduates.

Reports for Summer 1995 and Academic Year 1995–96, from the five programs currently receiving IRA funding, follow.

Mission to Planet Earth

Tunable Solid State Lasers and Optical Imaging

Director: Dr. Robert R. Alfano
Department of Physics
The City College of the City University of New York
New York, NY 10031
Date of Original Award: 1994

INTRODUCTION

The goal of this program is to address state-of-the-art imaging problems that include: developing improved laser sources; understanding the propagation properties of (turbid) media; utilizing time-gating detector methods; improving image quality through enhancement techniques; developing modeling and simulation algorithms; and enhancing the human-machine interface for improved system utilization. Undergraduate and graduate students participate in the research and acquire valuable experience with state-of-the-art equipment and techniques which are of interest to NASA missions as well as commercial product development.

RESEARCH ACCOMPLISHMENTS

The scope of the City College IRA program is extensive. In 1995–96, seven research projects, addressing the laser and imaging problems, were supported. The active staff encompassed 14 researchers on four campuses. Seven undergraduates and seven graduate students worked along with senior researchers. The major accomplishments are in the areas of laser development, optical imaging, and image processing and modeling.

Laser Development

We are developing tunable solid-state lasers that emit light in the near infrared region of the spectrum. Tunability is desirable to allow the user to select specific wavelengths that optimize systems for such applications as imaging, medical diagnostics, and optical communications. For solid-state lasers, the tunable range is determined by the lasing medium—a crystal whose structure and constituents determine the wavelengths produced.

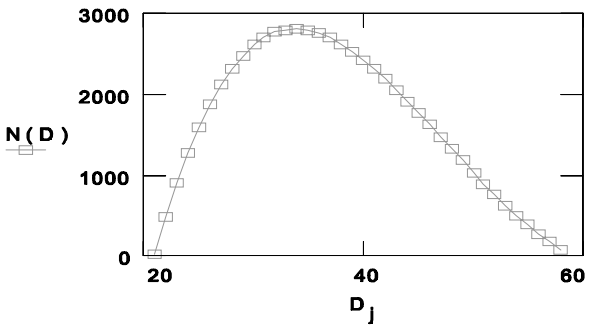
City College researchers have pioneered the development of chromium-doped forsterite (Cr^{4+}:Mg_2SiO_4) and have shown that it lases successfully in the region of 1.13–1.37 mm. To extend the emission range to longer wavelengths, a new laser material [chromium-doped germanate (Cr^{4+}:Ca_2GeO_4)] was developed. This material, called cunyite, emits in the range of 1.1–1.5 mm. This event was the first reported occurrence of lasing in chromium-doped germanate in the optical communication region.

Optical Properties of Turbid Media

A light-scattering technique has been used to obtain information on the properties of jet-fuel sprays. The scattered light patterns provide information on the number and distribution of fuel drops, which is useful in optimizing engine performance.

A coaxial injector spray system, based on specifications provided by NASA, was built to simulate data that will predict the performance of liquid propellant rocket engines. A light-scattering measurement facility with a tandem fluorescence apparatus was also built. It serves the dual purpose of analyzing the droplet size distributions produced by the coaxial injector spray system and characterizing the bubble distribution in sonicated aqueous environments. (In sonication, sound energy is used to break up bulk material into discrete particles.) We were able to measure the droplet size distribution of the injector spray as a function of the mass flow rate of water (see Fig. 1).

Figure 1. A typical droplet size distribution. N(D) = number of drops (arbitrary units), D_j = droplet diameter (microns). The mass flow parameters were (water) 0.003 kg/sec and (air) 0.002 kg/sec. Note: The distribution was measured 40 mm downstream of injector post.



Fluorescence Imaging of Tissues

Optical spectroscopy provides a noninvasive, real-time method for tissue diagnosis. Fluorescence (intensity) ratio instrumentation mapping systems can be used for the high-speed examination of large areas of tissue. To process large quantities of data generated by such a system, various image-processing tools are needed. Pseudo-color mapping is one tool that allows for the real-time assessment of fluorescent image data. In addition, developing image diagnostic tools requires calibration based on well-defined normal and malignant tissue samples.

During 1995–96, we developed and improved techniques to evaluate fluorescence from the surface and sub-surface

layers of different tissue types from the upper aerodigestive tract. Specifically, we focused on new scans with ratios that discriminate normal from preneoplastic and tumor tissues (see Fig 2).

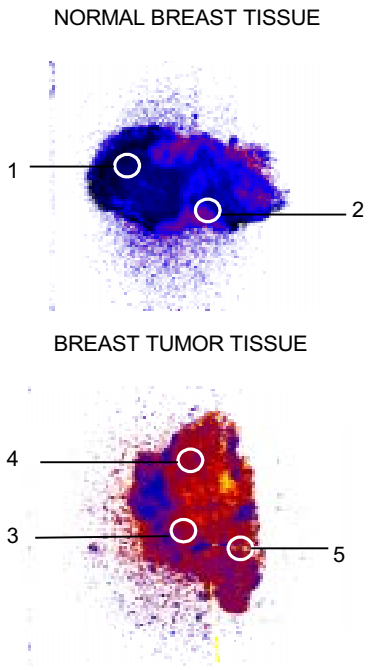


Figure 2 Images of normal and tumor breast tissue with biopsy sites

Image Reconstruction of Jet Spray and Turbid Media
This project involves the development of feasible theoretical models and expanded tools for image reconstruction of a jet spray and hidden objects in turbid media.

A geometrical optics model that simulates light propagation through jet drops is being developed. The program for this algorithm has been written and tested. Also, we have successfully reconstructed an image of a hidden object in a highly scattering media using experimental time-resolved light profiles from multiple source-detector pairs as input data. Our results show that an approximate reconstruction of the hidden object is possible.

Using ultra-fast light scattering to detect the drop distribution from a jet spray is a unique and interesting method that is able to image objects in motion at very high speed. The goal of our research is to invert time-resolved signals to determine shapes, and the distribution of drops, when a jet spray emerges from a nozzle.

We have developed a fast and noise-resistant inverse algorithm and have successfully reconstructed an image of a hidden object in a highly scattering media using experimental time-resolved light profiles from multiple source-detector pairs as input data. Diffusion theory was used for the forward model. Using a database technique, we obtained an image in 1 minute on a Silicon Graphics Inc. (SGI) Indy workstation.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

The project on tunable solid-state lasers is of direct and immediate interest to NASA's Langley Research Center program in remote sensing where efficient, reliable lasers, tunable in the 1.1-1.6 mm range, are needed for satellite-borne remote-sensing systems. The characterization of fuel droplets and sprays is needed for studies on propulsion systems at NASA's Lewis Research Center.

BENEFITS TO SOCIETY

The benefits to society from the developments in lasers and imaging systems in general are vast. Applications of the type of laser systems under development at City College include remote sensing of the Earth, optical communications, and medical diagnostics. Lasers continue to provide tools to solve important problems and will continue to do so in the future. As laser devices and systems are further developed, more applications will be realized.

The particular developments discussed in this report apply mainly to cancer detection. Developments using fluorescence-imaging spectroscopy to distinguish cancerous from normal tissue are of considerable value to medical diagnostics and clearly benefit society at large. Cancer, and in particular breast cancer, remains one of the most pervasive and costly national medical problems.

STUDENT ACHIEVEMENTS

The City College IRA program provides valuable research opportunities for students, many of whom are minorities who would not have access to high-level research and technology environments without the IRA program. Participating students, undergraduate and graduate, have worked on the IRA program alongside their mentors in the 1995–96 Academic Year and intersessions. All have benefited from their experience working with senior faculty researchers who are leaders in their respective fields. They have achieved co-authorship and have made presentations, both locally and nationally, to various groups and organizations.

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High Performance Database Management with Application to Earth Sciences

Director: Dr. Naphtali Rishe
School of Computer Science
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Date of Original Award: 1994

INTRODUCTION

In performance of this project, we are developing a highly parallel database system based on the semantic/object-oriented approach. Our research aims to significantly improve the usability and efficiency of highly parallel database computers and system clusters (tightly networked groups of systems). We are developing algorithms and a database management system that will have substantial advantages over current database systems. Our object-oriented system is based on the Semantic Binary Model of databases. Recent results in database theory and applications show considerable advantages of the Semantic Binary Model in comparison to the Relational Data Model. A semantic database system will have better logical properties: friendlier and more intelligent generic user interfaces based on the stored meaning of the data; comprehensive enforcement of integrity constraints; greater flexibility; spatial data; scientific data; and substantially shorter application programs. Our system will also provide higher efficiency for both small and massive numbers of processors, as well as better exploitation of parallelism for data storage and processing. We also conduct research on such theoretical and applied issues as database design methodology, database design tools, information analysis, multimedia databases, distributed databases, database languages, data compression, and spatial databases.

RESEARCH ACCOMPLISHMENTS

During the period covered by this report, we have made progress in developing theory and algorithms for database management, in designing and implementing our testbed parallel database machine, in developing testbed applications to implement on our database machine, and in recruiting student researchers.

Advancements in the theoretical aspects have been made, including: algorithms for very efficient database storage, querying, and visual presentation of generalized spatial functions; an efficient optimistic concurrency control algorithm and query optimization technique for a massively parallel B-tree with variable length keys, which is used to implement our semantic/object-oriented database system; an executable formal technique for architectural specification, analysis, and prototyping of distributed real-time systems; two new distributed deadlock detection and resolution techniques; a hierarchical algorithm for consistent check-pointing and recovery in distributed systems; and new techniques for query processing over intelligent public networks, which minimize the monetary cost of network usage for data transfer.

We have made progress in the design and implementation of our testbed prototype parallel database machine. The parallel B-tree with variable length keys mentioned above has been completed, and it is now being used to develop our semantic/object-oriented database system. This system, as described below, is being used by our researchers to store spatial data. Concurrently, we have built a prototype distributed database system that runs on personal computers over simulated ISDN lines; access to heterogeneous databases is made possible through ODBC (Open Database Connectivity) interfaces.

We have been collaborating with Earth science researchers to produce semantic schemas of databases of interest to Earth scientists. We have rendered both ocean temperature and ozone data in a lossless hyperquadrant form and have built a semantic database to contain the hyperquadrants. We have added new user controls to the system which have provided improved interaction between users and the databases. These controls include a zoom capability, access to data from several distinct satellites, and improved control over the display of the "animated movie" that is generated from the database. We have imported both daily and monthly ozone data from the Nimbus 7 and Meteor 3 satellites for periods of up to 14 years and use this information regularly in our trial databases. We have begun to import reflectivity data from the Meteor 3 satellite and expect to use this information together with the ozone data to generate ultraviolet flux estimates as an example of our system being used to access two separate databases in a single application.

We have continued to recruit promising graduate students to work on this project and to train them in semantic databases, parallel processing, and spatial data handling. The faculty participating in the research have exposed students in the courses they are teaching, which relate to databases and parallel processing, to the ideas behind the research being conducted by our group.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

Our IRA research aims to support NASA's need for efficient access to the vast quantities of data that are being collected by satellites. An example of the type of data

access our system will enable is embodied in the ozone data mentioned above.

BENEFITS TO SOCIETY
Our research indirectly benefits the average citizen by allowing scientific researchers to perform their work more efficiently. In the future, the database technology that is being developed will be able to provide more efficient information access for everyone.

STUDENT ACHIEVEMENTS
During the reporting period, four NASA-supported undergraduate students received their bachelor of science degrees in computer science from Florida International University (FIU). Three of these students have chosen to begin their graduate studies at FIU; the other has taken a position in the industry. Two NASA-supported graduate students received their master of science degrees in computer science. One has gone on to work in the industry, and the other is now a NASA-supported Ph.D. student at FIU. NASA-supported students have co-authored three refereed papers and one invited paper. Two of these papers were presented at conferences by NASA-supported students.

Additional NASA Enterprise Areas: Aeronautics and Space Transportation Technology, Human Exploration and Development of Space, and Space Science
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Land Management in the Tropics and its Effects on the Global Environment

Director: Dr. Brad R. Wiener
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University of Puerto Rico at Rio Piedras
San Juan, PR 00931-7717
Date of Original Award: 1995

INTRODUCTION
This project examines how land-use changes in Puerto Rico over the last 50 years have affected plant and animal communities, stream-flow and sediment yield, soil and water chemistry and microbiology, and greenhouse gas emissions to the atmosphere. During these five decades, agriculture has been abandoned in large areas of this tropical island, and forests have been allowed to regenerate naturally. A time-series of aerial photographs of the entire island, remotely sensed imagery, and geographical information system (GIS) overlays of climate, soils, and other factors allow researchers to select sites that have undergone different periods of natural succession, but that are otherwise similar. Coordinated studies at these sites are leading to the development of models of the effects of land-use changes on biological communities and other environmental factors. When this project is completed, we will have developed a detailed understanding of environmental effects of land-use changes in Puerto Rico. At the same time, by initiating similar studies at other sites in the Caribbean basin, we will understand the applicability of these models elsewhere in the tropics.

RESEARCH ACCOMPLISHMENTS
The Landscape-scale Patterns Group continues its research and student training in the acquisition and manipulation of remotely sensed imagery and in the construction of spatial databases of topography, geology, soil type, and current and historical land use. These data are being used for interpretation, additional site selection, and watershed modeling of stream and sediment flux through time.

In the Ecosystem Recovery Group, permanent plots established by the USDA Forest Service throughout Puerto Rico have been resurveyed to document rates and pathways of forest recovery. Intensive studies of forest recovery following various agricultural uses on different geological substrates have been carried out in southwestern, southeastern, and northeastern Puerto Rico, and additional sites have been established in the north-central and northwestern regions. Plant physiology research has focused on interactions among plant species, nutrient availability, and carbon gain. Group members also made a reconnaissance visit to the Dominican Republic to select sites for off-island expansion during the last 2 project years.

In the Ecosystem Processes Group, soil exchanges of nitrogen trace gases and methane are being measured in both wet and seasonally dry sites. Rates of nitrogen cycling are being related to moisture availability and the abundance of nitrogen-fixing plant species. Gene probes and DNA hybridization techniques are being used to quantify soil bacteria involved in the release of greenhouse gases. Roles of earthworms in soil nutrient cycling and greenhouse gas exchange are also being evaluated by both monitoring and manipulation studies. Island-wide data on climate, soils, stream flow, and stream sediment yield are being used for hydrologic and sediment modeling. Laser spectroscopy studies are examining the reaction kinetics of nitrous oxide, the hydroxyl radical, and other tropospheric constituents.

Project collaborations are under way with the Harvard Forest, the University of Illinois, Michigan State University, NASA's Stennis Space Center, the USDA Forest Service, and several government agencies in Puerto Rico. Articles produced by all three groups (Landscape-scale Patterns, Ecosystem Recovery, and Ecosystem Processes) have been published in peer-reviewed journals, with more in preparation. Presentations on this project were submitted for the February 1997 NASA University Research Centers Technical Conference (URC-TC '97) in Albuquerque, New Mexico, and the June 1997 Third AIDIS Region 1 Conference in San Juan, Puerto Rico. A Symposium integrating all NASA-funded research in Puerto Rico is being planned by the University of Puerto Rico (UPR). A World Wide Web site has also been established for the project (http://web.uprr.pr).

RELEVANCE TO NASA STRATEGIC ENTERPRISES

NASA's Mission to Planet Earth uses Earth-orbit as a vantage point to better understand Earth processes. The Puerto Rico IRA adds ground-based observations and ground truths of environmental patterns and processes in the tropics to increase the value of NASA's observational data. This project has been highly rated by its Technical Review Committee for its relevance to this Strategic Enterprise.

BENEFITS TO SOCIETY

Benefits of the Puerto Rico IRA are both general and specific. The project is developing techniques to utilize remotely sensed imagery and other spatial data to assess conditions and change of tropical lands and to understand the implications of these changes to hydrology and other environmental conditions. Government agencies and commercial interests will be able to use this information to better understand how changing land use in the tropics affects biological diversity, hydrologic cycles and water quality, and exchanges of greenhouse gases with the atmosphere. In addition, research on the recovery of degraded lands is intended to suggest land-management strategies for other tropical areas that can reestablish forests, regain site fertility, and mitigate negative environmental effects.

Project-specific benefits include student training, substantially upgrades to the UPR research infrastructure, and a description of the research for the general public on a radio station in San Juan. Initial project results are being used to seek additional funding from the Department of Energy's Hispanic Collaborative for Research and Education in Science and Technology (HiCREST) Program.

STUDENT ACCOMPLISHMENTS

Undergraduate, M.S., and Ph.D. students are being recruited and trained in land classification from aerial photographs and satellite images, GIS, spatial modeling, field analysis of plant community succession, plant physiology, hydrology, soil ecology, modern microbiology, and laser spectroscopy. A student training program in remotely sensed image analysis was conducted at Harvard Forest in Petersham, Massachusetts. The University of Massachusetts will conduct a follow-up course in air photo interpretation in Puerto Rico during the summer of 1997. Students have made research presentations both in Puerto Rico and at international scientific meetings. Students are also being trained in new UPR course offerings in remote sensing and landscape ecology. Five students have served as co-authors on five papers published or submitted this year, including a McNair Award recipient.

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Space Science

The Use of Decentralized Control in Design of a Large Segmented Space Reflector

Director: Dr. Helen Ryaciotaki-Boussalis
Department of Electrical Engineering
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Los Angeles, CA 90032
Date of Original Award: 1994

INTRODUCTION

The Control and Structures Research Laboratory (CSRL) at California State University at Los Angeles has been established for the design and fabrication/assembly of a testbed resembling the complex dynamic behavior of a space-segmented reflector telescope. Advanced technologies for decentralization, precision pointing, vibration attenuation, fault identification, controller reconfiguration, adaptive/robust control, neural-fuzzy control, system identification, and reflector shape control will be developed and experimentally validated on the testbed. These new technologies are of immediate interest to NASA, the aerospace industry, and the commercial sector.

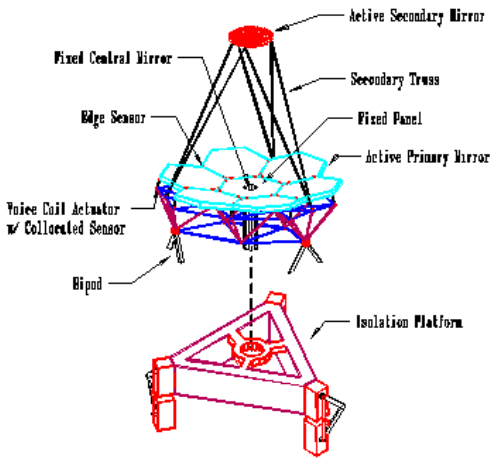

Figure 1 Description of a CSRL test-bed

RESEARCH ACCOMPLISHMENTS

The thrust of the CSRL research is to address, in an integrated way, the problems associated with control and structures interaction, distributed control of multi-input/multi-output systems, optics, electronics, actuator and sensor design, and digital implementation. One of the main research objectives is to demonstrate the advantages of a decentralized control approach to large-scale systems in a unique way.

The contributions of the CSRL research during Academic Year 1995–96 include:

- New methods in structural optimization
- Design of high-performance/high-bandwidth actuators
- Data acquisition and digital signal processing for large structures
- Development of methods in structural decomposition as applied to large, flexible structures
- Application of robust control techniques, including PID, LQR, and H-infinity
- Development of neural network controllers

RELEVANCE TO NASA STRATEGIC ENTERPRISES

Control architectures developed at CSRL are applicable to NASA astronomical missions and to other applications that employ segmented reflectors (such as SELENE). Results obtained within the CSRL research program are directly applicable to missions such as the Submillimeter Explorer (SMME), the Submillimeter Imager and Line Survey (SMILS), and the Large Deployable Reflector.

Engineering students at the Control and Structures Research Laboratory

The decentralized control results, in particular, can be extended to enable missions, such as multispacecraft formation flying. Decentralization techniques are also well suited for microspacecraft attitude control, using multiple miniaturized sensors distributed on the vehicle. Future CSRL research in the area of failure detection and reconfigurable control will present a direct benefit to autonomous spacecraft control research and development currently under way in NASA and the Department of Defense.

BENEFITS TO SOCIETY

The decentralized results obtained can also be applied to the control of the Department of Energy's Long Arm Manipulator and to intelligent highways and vehicles. Adaptive control and neural network-based vibration attenuation and shape control results can be extended to acoustic disturbance isolation, which is of interest to the Department of Defense and to the automotive industry. Adaptive control results are directly applicable to advanced

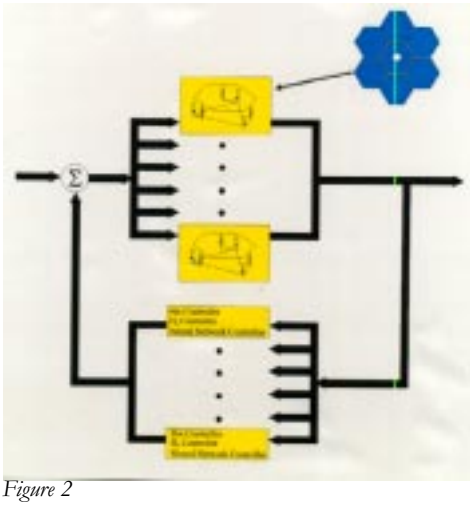

Figure 2

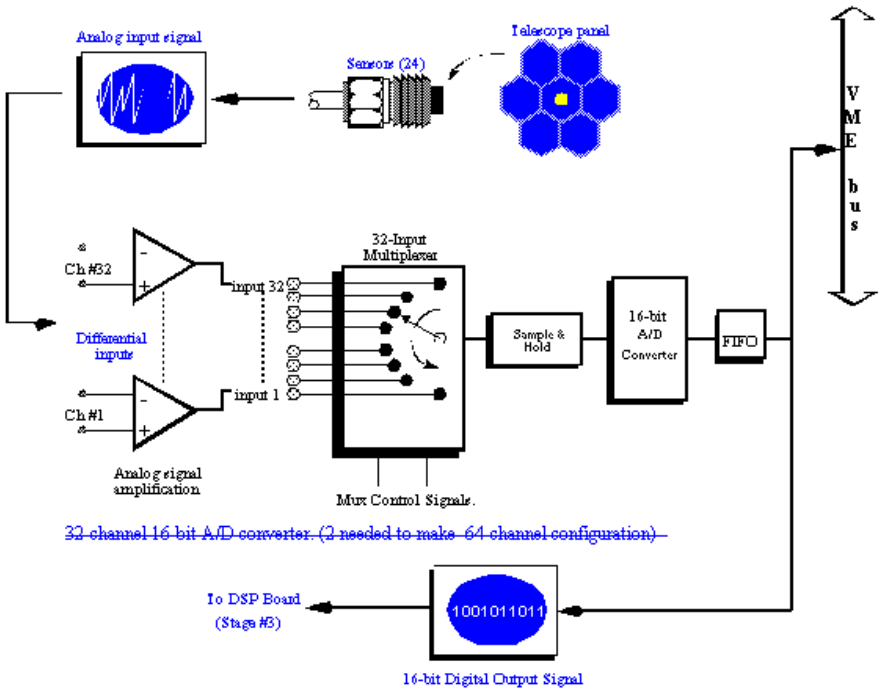

Figure 3 STAGE #2 Analog-to-digital conversion

urban traffic control systems, such as intelligent highways and vehicles.

STUDENT ACHIEVEMENTS

The CSRL project student achievements include:

- More than 20 minority engineering students completed design projects and M.S. theses while supported by the project.
- Four minority students assumed positions with major engineering firms, including Rockwell International, TRW, Phillips Electronics, and Boeing.
- Students participated in the preparation of three articles published in technical journals.
- Students co-authored and presented several technical papers published at national and international conferences.
- A Ph.D. student supported by the project was awarded a $6,000 Lockheed-Martin Graduate Fellowship.
- Several undergraduate minority engineering students supported by the project continued their studies toward an M.S. degree.

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Alliance for Nonlinear Optics

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INTRODUCTION

The Alliance for Nonlinear Optics consists of a group of seven faculty members at five universities who have complimentary backgrounds and a common interest in working in the area of nonlinear optics (NLO). The schools are Alabama A&M University, New Mexico Highlands University, Spelman College, the University of Alabama in Huntsville, and the University of Puerto Rico at Mayagüez. This group provides capabilities for the theoretical prediction of materials with NLO properties, synthesis of materials, testing, thin film and crystal growth, and device fabrication. Capability in the area of x-ray crystallography has been added recently.

The main goal of the alliance is to conduct the basic research needed to make it possible to develop practical optical devices that utilize nonlinear optical phenomena. To achieve this goal, the group conducts research at all levels of the problem, from theoretical calculations to the fabrication of prototype devices. Emphasis has been placed on materials, because it is perceived that the lack of

good materials is a major impediment to progress. While most of the work has involved organic materials, inorganic materials are considered where appropriate. Thermal stability, processability, and high nonlinearity are objectives in the materials being sought.

Short-range commercial prospects for this technology include optical switches, waveguides, optical filters, and other devices. Long-range prospects, such as optical computers and telecommunications applications, are probable.

RESEARCH ACCOMPLISHMENTS

The Alliance has had numerous successes during the past 2 years. One example is that a new method of producing thin films has been developed. This method, known as the plate-guided method, allows the growth of a single crystalline film of specified thickness between two glass plates. A patent is pending on this process. Further development of the technique is under way.

The knowledge of second-order molecular susceptibility (β) of optically nonlinear organic materials is important in understanding the relationship between molecular structures and nonlinear optical properties. A study of solvent effects on nonlinearity as measured by Electric Field-Induced Second Harmonic (EFISH) and Elastic Second Harmonic Light Scattering (ESHLS) has been under way for some time. The work to date is only applicable to small molecules, although an extension of the technique for large molecular systems is in progress.

The ability to predict third-order nonlinearity has recently been developed. Also, the second-order method has been extended to three-dimensional molecules. Improvements in the area of theoretical calculation are continuing, and further applications should provide new molecules for study in the future. Specifically, work on molecular clusters (dimers and larger) are under way. This is important because many molecules that would be good NLO materials do not ultimately prove to be useful, because they crystallize in a centro-symmetric manner. Molecules with (β) values of about three times better than those used to date have been identified, and additional molecules that should have values of 10 to 20 times better than previous molecules have been suggested for calculations.

The growth of single crystals via the Bridgman-Stockbarger technique has been further developed. Significant improvements in the design of the apparatus have been made, and crystals of DIVA have been successfully grown up to about 1 centimeter in diameter.

Studies of the branching effect of a single optical beam in dye-doped polymeric single-mode slab waveguides have evolved to the point that a good theoretical correlation between experiment and theory now exists. The effect is associated with a permanent refractive index decrease accompanying upconverted dye photobleaching at low-power CW pumping. Practical applications involving waveguide formation exist, if the phenomenon can be controlled.

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NETWORK RESOURCES AND TRAINING SITES

In 1991, in recognition of the fact that many HBCUs and OMUs lacked the in-house expertise required to develop and support a campus local area network with an interconnect to the Internet, the NASA Office of Equal Opportunity Programs (OEOP) created the Minority University-Space Interdisciplinary Network (MU-SPIN) program to improve electronic information exchange and sharing of computational resources at HBCUs and OMUs participating in NASA-related research. In 1995, in order to enhance HBCU and OMU efforts in achieving MU-SPIN program goals, OEOP funded seven regional Network Resources and Training Sites (NRTS) at HBCUs and OMUs under the IRA program. The intent of the NRTS is to strengthen the capacity of minority universities to provide excellence and state-of-the-art mathematics, science, engineering, and technology training and support research infrastructure development, thereby increasing opportunities to participate in and benefit from NASA programs.

The Internet plays a significant role in how NASA, academe, private industry, and other government agencies collaborate to achieve scientific, technical, and educational goals. In addition to bringing the benefits of computer networking and Internet connectivity to a greater number of HBCUs and OMUs, the purpose of the NRTS is also to bring the benefits of Internet connectivity to elementary and secondary schools serving predominantly minority populations.

NRTS are required to provide the following services for other minority-serving institutions identified in the region: assessment of specific needs; design of computer networks for the institutions; network connectivity; a network user resource center; and supplemental training for technical advancement and relevant usage for research and curriculum reform for the MSET faculty and student bodies of these institutions.

During Summer 1995, and Academic Year 1995–96, NRTS affected more than 58 colleges and universities, 28 elementary schools, 30 middle schools, and 38 high schools in 15 states. This impact included:

- More than 175 training sessions for university, college, and K–12 personnel
- Support for various research and education initiatives at 32 colleges and universities
- Support of curriculum initiatives at two colleges and universities
- Support of curriculum initiatives at eight K–12 schools
- Development of research connections to eight NASA Field Installations

In addition, NRTS programs were supported by 23 industrial partners. Brief reports from each of the NRTS follow.

An Urban Collaboration for Network Connectivity and Internet Access

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Date of Original Award: 1995

INTRODUCTION

The Northeast NRTS is based at the City College of New York (CCNY) of the City University of New York (CUNY). The CUNY campuses and schools in the NRTS consortium participate in the Institute for Climate and Planets (ICP), a research and education program sponsored by the Goddard Institute for Space Studies (GISS) with the collaboration of the CUNY Alliance for Minority Participation (AMP) and the New York City Board of Education. Participating CUNY campuses are Medgar Evers College, York College, Queensborough Community College, and LaGuardia Community College. Participating high schools include George Washington High School, Bronx High School of Math, Science and Technology Research (MAST), and A. Philip Randolph High School.

A major component of the ICP plan is the development of local campus/precollege research and education infrastructures to engage a wider pool of faculty and students. Most of the participating campuses and schools in the ICP, however, lacked Internet access and/or adequate local area network infrastructure to support fully an ICP-based research environment. The objective of the NRTS is to provide the required network infrastructure, Internet access, and technical support infrastructure that will enable the development of these "satellite" research and education centers.

RESEARCH ACCOMPLISHMENTS

To expedite network delivery for ongoing research and education activities, plans were formulated by the NRTS to provide significant funding and technical support for the participating ICP campuses and schools lacking high-bandwidth Internet access and local area networks. In the first year, network infrastructure funding was provided for Medgar Evers College, LaGuardia Community College, Queensborough Community College, and MAST High School. At Medgar Evers, the NRTS provided an Ethernet component for the existing Token Ring network to provide distribution and Internet access for the Biology, Math, Physical Sciences, and Computer Science Departments. Queensborough received support for the partial implementation of an ATM-based fiber backbone. NRTS funds were used at LaGuardia to support the implementation of a fiber-based Fast Ethernet backbone and infrared hardware to provide local area network integration for the Computer and Information Sciences Department and LaGuardia Middle College High School. MAST High School was provided with a Fast Ethernet backbone and has been designated as one of the New York City Board of Education Technology Centers. Internet access was also provided for MAST High School and the Bronx High School of Science with NRTS funds.

Technical staff training workshops were provided by the NRTS in topics that include network and TCP/IP administration, OS-specific network maintenance, and TCP/IP integration. Participants in these workshops included faculty/staff with technical responsibilities, in addition to students. The NRTS is also providing remote network management and administration for high schools in the consortium as they are developing technical skills.

Basic Internet training was also provided for faculty, staff, and students in the consortium, including workshops on introduction to the Internet, integrating the Internet into Mathematics, Science, Engineering, and Technology (MSET) curriculum, and introduction to HTML. For advanced users, the NRTS provided workshops and/or courses for webware/courseware application development, including advanced HTML, CGI programming, and Java. Almost 800 MSET faculty, staff, and students were trained in the first year. Additional workshops provided by the NRTS included New York City staff development Internet training for K–12 math and science teachers. The NRTS also provided workshops on electronic commerce and the Internet, targeting minority businesses and non-profit organizations. Further, NRTS training facilities and materials were used for workshops at schools participating in the National Science Foundation (NSF)-funded Weather Watch program, as well as K–12 parents, teachers, and librarians.

Students were supported by the NRTS at CCNY, Medgar Evers College, and MAST High School to assist with the integration of the networks with planned ICP-related research and education activities. The NRTS plans to provide student support at each campus and high school for both network integration and participation in ICP-based research activities.

BENEFITS TO SOCIETY

Enabling network infrastructure, technical support, and training and providing continuing workshops for faculty and students have stimulated local development of ICP-related programs at campuses and schools participating in this initiative. Faculty and students in research courses under way on climatology and satellite imagery, ocean

models, and planetary science are able to communicate with GISS research scientists electronically and access satellite and other datasets. Curriculum development initiatives in Earth science, physics, meteorology, and remote sensing have expanded to incorporate Internet-accessible courseware. More generally, MSET departments participating in the network and application design process have been stimulated to integrate Internet-accessible network resources into existing curricula. Finally, the technical models developed with respect to network design, implementation, support, and training have been made available for general education and community access.

STUDENT ACHIEVEMENTS

Approximately 40 faculty and students are supported by the ICP to work with GISS scientists on research projects related to global climate change and planetary science. Some of the outcomes of the ICP include faculty and student publications and presentations, Earth science curriculum development, and the development of multimedia software supporting undergraduate physics and meteorology curricula. Students at three of the four high schools submitted a total of four Westinghouse projects based on ICP research.

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Regional Network Resources and Training Site at ECSU

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Date of Original Award: 1995

During the first year of the Elizabeth City State University (ECSU) NRTS program, the following progress was accomplished for each of the following initial goals of the program:

Expand networking capacities of the ECSU campus to provide access to all MSET faculty;

- The ECSU Technology Department located in Dixon Hall now has internet connectivity through twisted pair wiring.
- The ECSU Talent Search Program located in Lane Hall now has internet connectivity through twisted pair wiring.
- ECSU's Lester Hall now has upgraded its internet connectivity by using an ATM interface.
- ECSU's J. R. Jenkins Science Complex has internet connectivity through twisted pair wiring.

Provide Internet access for predominantly minority attended K–12 schools in the ECSU region

- Elizabeth City Middle School now has ECSU as service provider.

Establish linkage with industrial partners

- Albermale Hospital has proposed three student internships.
- ANDET Systems, Inc., provided three technical people.
- The U.S. Coast Guard at Elizabeth City provided NETDAY96 support.

Establish linkage with a NASA Installation:

- ECSU established linkage with the Langley Research Center through flexible circuits technology and the ATLAS Connectivity Model.
- ECSU established linkage with Goddard Space Flight Center through Integration of the Internet into the classroom, and high-performance networking.

Provide network training and facilitate network opportunities for MSET faculty and students at HBCUs and OMUs, as well as for teachers in predominantly minority-attended K–12 schools in the ECSU region:

- The ECSU NRTS Summer 1996 Research and Training Project supported the five elementary and secondary schools/programs in the Roanoke Valley/Camden/Pasquotank/Perquimans counties. This 4-week summer research and training project focused on Internet essentials, creating a web page, network tools, and resources. In addition to offering a meaningful summer study experience, the program offered field trips and lectures.

The secondary school training program was designed to give educators and students intensive exposure to Internet and connectivity concepts. During the 4-week program, participants were exposed to many computer platforms, including Sunspace, Silicon Graphics, PCs and Macintosh. Their ability to move smoothly between platforms and to recognize the appropriate uses of each platform was very

important to the success of this program. Participants began their program by studying network etiquette and ethical uses of the technology–the rationale being that as wonderful and powerful as the computer is, it still remains in the domain of the human operator to make value judgements and to make responsible decisions as to its use.

This program was funded by the MU-SPIN office of the Goddard Space Flight Center. The Langley Research Center is also a partner in the NRTS at ECSU. Both Goddard and Langley provided visiting lecturers, which added a unique dimension to the program, and represented an array of programs that NASA supports. Each visitor presented effective ways to integrate the Internet into the curriculum and to bring the technology to secondary school classrooms.

Participants learned not only to navigate the Internet, but also to join in the effort to design the look and feel of cyberspace. Educators aggressively joined their effort to design web pages for their schools, which documented the individual school's mission, programs, student activities and much more. With the able assistance of the NRTS staff and ECSU student workers, students designed their individual web pages which implemented advanced concepts, including animation, tables, and frames.

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Morgan Network Resource Training Site

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Date of Original Award: 1995

During the first year of the Morgan State University (MSU) NRTS program, the following progress was accomplished for each of the following initial goals of the program:

Provide outreach Internet/World Wide Web technical support and training to the faculty of MSU and area colleges:

- Bowie State University and Central State University have received funding in support of their local area outreach programs.
- University of Maryland Eastern Shore received technical support in the form of human resources.
- Coppin State completed hardware installation and cabeling for internet access in its Department of Natural Science.
- Baltimore City Community College delivered the first increment of laboratory workstations.
- The School of Engineering, the Center of Excellence in Math and Science and the Department of Mathematics all have internet connectivity as a result of the NRTS.

Provide outreach Internet/World Wide Web technical support and training to area K–12 teachers:

- The NRTS funds leveraged with Baltimore Urban Systemic Initiative (BUSI) provide internet access to Baltimore City Public Schools. There are 11 HBCUs and OMUs and public schools serving the predominantly minority students connected to the Internet.
- ISDN lines were connected and installed at Frederick Douglass High School, Southern High School, Harlem Park Middle School, Gwynns Falls Elementary School, and Matthew A. Henson Elementary School.
- Designated students supported by this grant are in the process of developing partnership schools web pages.
- Workshop training sessions for all the partnership schools continue, and we have trained approximately one-third of the teacher population.

Provide outreach Internet/World Wide Web technical support and training to selected area K–12 students.

- There was a partnership and collaboration with the NSF-funded Sky Math Program for middle school teachers and students.

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Establishment of a NASA Southwest Regional Network Resources and Training Site

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Date of Original Award: 1995

A NASA Southwest Regional NRTS has been established at Prairie View A&M University. Its goal is to create a high-speed digital network consisting of data and video channels linking a series of remote sites in the southwestern United States. This network will result in the creation of a virtual university for the sharing of resources by all project participants. Additionally, the network will provide for the enhancement of the learning experience for the traditional learning community (K–12 and college students) served by the various partners as well as provide lifelong learning opportunities for the larger adult community.

The current area of impact includes the States of Texas, Louisiana, Oklahoma, and New Mexico. Participants in this collaborative effort include Prairie View A&M University (Prairie View, Texas), Texas A&M University–Corpus Christi, Southern University at New Orleans, Paul Quinn College (Dallas, Texas), Jarvis Christian College (Hawkins, Texas), Huston-Tillotson College (Austin, Texas), Texas College (Tyler, Texas), Wiley College (Marshall, Texas), Texas Southern University (Houston, Texas), Navajo Community College (Shiprock, New Mexico), Central Consolidated School District (Shiprock, New Mexico), Hempstead Independent School District (Hempstead, Texas), Aldine Independent School District (Houston, Texas), and North Forest Independent School District (Houston, Texas). Each of these institutions is either an HBCU, a Native American-Serving Institution, or one that serves a majority population of underrepresented participants in science, mathematics, and/or engineering.

Activities associated with the 5-year development plan have been initiated. Specifically, full T-1 Internet connectivity has been established at Hempstead High School, Drew Middle School in Aldine Independent School District, North Forest Independent School District's Smiley High School, Southern University at New Orleans, Paul Quinn College, Jarvis Christian College, Huston-Tillotson College, Texas College, Wiley College, Navajo Community College, and Shiprock and Newcomb High Schools in the Central Consolidated School District. A computer laboratory has been installed at Langston University. Full Internet connectivity has been established for the Departments of Chemistry, Biology, and Mathematics at Texas Southern University.

A video network has been established that will link Prairie View A&M University, Paul Quinn College, Jarvis Christian College, Wiley College, Huston-Tillotson College, and Texas College. This network utilizes the Texas VidNet video network and permits distance learning and videoconferencing among the partners.

Major training activities have been conducted for the partner schools. A training workshop held during the summer of 1996 focused on the building of computers and computer networks. This workshop has resulted in successful projects being initiated in schools throughout Texas. Future training efforts will include network management and development of distance learning presentation skills, as well as integration of the Internet into the curriculum.

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Center for Network Resources and Training

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INTRODUCTION
The South Carolina State University (SCSU) Network Resources Training Site (NRTS) is largely a rural consortium consisting of small HBCUs and K–12 schools. Only SCSU and Florida International University (FIU) conduct a large amount of research. The goal of this project is to provide increased Internet connectivity at SCSU and partner schools.

RESEARCH ACCOMPLISHMENTS
The first year of the SCSU NRTS focused largely on rewriting the technical plan, organizing a large partnership program, and implementing connectivity to the members of the consortium. A rewrite of the original technical plan was required by MU-SPIN because of comments by the technical reviewers regarding lack of cutting-edge

technology and dependence on proprietary systems. A variety of technical issues were examined, and discussions were held with numerous commercial vendors and universities outside of the consortium. A revised technical plan and budget were submitted, and in March 1996, they were accepted by MU-SPIN. The SCSU NRTS then moved forward to implement the technical plan with the primary goal of connecting all partner schools to the Internet at speeds of 56/64 Kbs or higher by the end of the first year, thus exceeding the requirements of the Cooperative Agreement which mandated modem connectivity at 19.2 Kbs by year end. This goal was accomplished with all schools, except Claflin College and Morris College, connected by September 30, 1996. The two remaining partners were connected at the beginning of the second fiscal year, in October 1996.

The dramatic change in connectivity to the partner schools cannot be overstated. On October 1, 1995, only 2 schools of the 12 in the consortium had Internet connectivity: SCSU and FIU, at 1.5 Mbs. The other 10 members had no connectivity or had low-speed modem connections used almost exclusively for administrative purposes. Excluding the technology-rich FIU campus, at the beginning of the first year, only the faculty, staff, and students at SCSU had limited Internet access, consisting only of E-mail, Telnet, and FTP capabilities and operating in a nonwindows ("dumb terminal") environment. At the end of Year 1, there was a three-fold increase in Internet access. Again excluding FIU, faculty, staff, and students in the remaining 11 schools had windows-based connectivity at speeds of 56/64 Kbs or higher.

The time and effort spent rewriting the technical plan meant that implementation of the educational plan was delayed until the summer of 1996, awaiting connectivity and installation of a training laboratory with new Pentium-class computers at SCSU. Once the training laboratory was installed in June 1996, training moved forward with an emphasis on training faculty members first, so that they might incorporate Internet resources in their coursework beginning in the fall of 1996. In the second fiscal year (beginning in October 1996), the emphasis has shifted to training a large number of students as well as faculty members.

Each member of the consortium has implemented their own technical plan that is unique to their school. In some cases, this has meant installing a single laboratory that is used by the entire campus. In the case of some other college partner schools, several existing laboratories have been upgraded so that Internet access is available across campus. The regional steering committee for the consortium, which consists of a site coordinator and technical coordinator from each partner school, decided that each member of the consortium would have their own Internet access through a commercial provider rather than through the NRTS. This allowed for maximum independence for the partners and minimized potential technical bottlenecks. This was possible to implement with minimum financial impact on the NRTS budget, because of the availability of leveraged funding at some of the college sites and because the State of South Carolina decided to fund Internet connectivity for all K–12 schools in the State.

The research at SCSU has been significantly impacted by the NRTS in the first year. Members of the Department of Physical Sciences have used the new connectivity and technical support staff to enhance their research capabilities. In the field of astronomy, one faculty member was able to submit as Principal Investigator a Cycle 7 Hubble Space Telescope proposal in September 1996. This proposal was accepted by the Space Telescope Science Institute and was awarded 13 orbits of observing time during Cycle 7. The use of FTP, Telnet, and Netscape was critical to formulating and submitting a collaborative proposal, which includes Co-investigators from Rice University and Arizona State University. Similarly, work by members of the Physics faculty and staff, in collaboration with Clemson University under a Department of Energy-funded grant, is far more efficient now that Internet connectivity is available in their superconducting laboratory. A Chemistry faculty member is now able to remotely access his data and software at the Medical University of South Carolina, whereas he was previously forced to travel by car the 180 miles round trip each time he wanted to work on his research.

In the second year, the SCSU NRTS will further expand its support of research at SCSU and its partner schools in all technical fields, through increased faculty and student training and the development of on-line research resource and databases. In particular, emphasis will be placed on the three areas of expertise identified by the SCSU NRTS and MU-SPIN: astronomy, materials science, and environmental science.

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NASA/TSU Network Resources and Training Site

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Date of Original Award: 1995

INTRODUCTION

The purpose of this project is to provide high-speed Internet connections to HBCUs, OMUs, and elementary and secondary schools with significant numbers of minority students. A second, more long-term purpose is to increase the number of minority representatives in the MSET professions.

RESEARCH ACCOMPLISHMENTS

Campus Network Committees were established at Tennessee State University (TSU) and at all of the satellite institutions. Many of these committees not only include the MSET departments, but also extend to other areas of the participating institutions. This has enhanced overall communications on the campuses related to computing and particularly enhanced interest in the Internet and its uses in education and research. T1 Internet connectivity was established at the NRTS site by installing a Domain Name Server (www.tsuniv.edu), with direct connectivity to the nearest point of presence (POP) on the Internet. The research and academic departments and student labs located in the Williams Campus facilities gained much-improved performance through this server and the direct Internet connection. Connectivity on the Main Campus is through the T1 line provided by TSU. Other groups that benefit from these infrastructure enhancements are the NASA, Department of Energy (DOE), and National Science Foundation (NSF) research and education programs housed in the Center of Excellence (COE) for Information Systems and Management.

The Center for Automated Space Science (CASS) is a NASA project housed on the Williams Campus. This Center directs the largest group of remotely programmed and computer-controlled telescopes in the world. These four telescopes (soon to be six) are located on a mountain in Arizona. The astronomers housed on the Avon Williams Campus of TSU make their computerized observations and receive data via the Internet.

The Center for Computational Methods, funded by DOE, uses the Internet for collaborative research with distant scholars. The Explorers of the Universe is a TSU-funded project where students in high schools at several sites across the United States use the Internet to perform collaborative astronomical research.

T1 connections are also in place at Lane College, Knoxville College, and Meharry Medical College. The local area network design for the TSU Campus is in place, and it is significantly implemented in the MSET departments. Enhancements were made this year, with upgrades of the connection speeds, with the addition of the server discussed above, and with new connections in 40-plus MSET faculty offices. The School of Agriculture, with help from the NRTS staff, and because of the existence of the campus backbone, has received a grant from the U.S. Department of Agriculture for computer enhancements in the agricultural sciences.

A minimum of 56-kbps dedicated-line connections are or will be in place by fall of 1996 at all of the satellite institutions. This provides Internet connections for all of the institutions served by the NASA/TSU NRTS. All of these are independent connections to the local POP. The Domain Name Server is on the World Wide Web, and the Home Page features descriptions of education and research activities available via the Internet. The Center of Excellence Home Page features the projects discussed above with support from the NRTS. The User Support Office is functioning, and is still being further formalized and improved. Formal documents, procedures, documentation, and training are in progress. The services of this office will be extended beyond the original 9 NRTS campuses and satellites. These services are being extended to the Twenty-First Century Schools, and the Schools for Thought of Metropolitan Nashville/Davidson County Public Schools (Metro). These 29 schools are designed to enhance the use of computer technology and the Internet in the educational process of the public school classroom.

Help Desk services are being provided to these schools by the NRTS. In exchange for this service, Metro and the State of Tennessee provide all connectivity and computers at these 29 schools and the ISDN connectivity at Kings' Lane (not a Twenty-First Century School). This has resulted in a significant leveraging of funds. The computers and connections at Pearl-Cohn Comprehensive High School cost in excess of $470,000 for the initial purchase and installation. The annual costs of the connections and maintenance will also be paid by Metro. The Help Desk is open from 6:30 a.m. to 5:30 p.m. Central Time. The calls are answered in the order they are received. The full-time personnel and students manning the desk are trained to answer as many questions as possible, and they also know where to refer the caller when answers cannot be provided from the Help Desk. All of the calls are logged for the

tracking of user inquiries and to assist in the development and improvement of the frequently asked questions for the users.

The Regional Network Committee was established and has met three times. Attendance was good, and communications with the members of the committee and other staff and faculty at the satellite campuses have likewise been good. Training, including that for the remote sites, has been provided on the TSU Campus to students and faculty. In addition, dedicated workshops were held for Kings' Lane Middle School on the TSU Campus. The MU-SPIN training programs, part of the NRTS agreement and services, have been attended by individuals from twelve different institutions.

BENEFITS TO SOCIETY

As noted above, the funds of this grant have been significantly leveraged. Of the seven students on the project this year, only two were funded through the grant. The others were funded through Vocational Rehabilitation, Tennessee State University, and the School of Business Internship programs. The Help Desk service being extended to the Twenty-First Century Schools is a result of the contribution of more than $470,000 by the State of Tennessee and Metro for the connections, server, wiring, and computers at Pearl-Cohn (180 connected stations for students and faculty). Metro and the State of Tennessee are also providing the ISDN connectivity for Kings' Lane. The other Twenty-First Century Schools represent an investment of more than $4 million in the use of the Internet for education. Many of the schools have very significant minority enrollments. This expansion represents the growth of the NASA/TSU NRTS project from the original 9 institutions (with 2 added), to a total of 33 schools being served. This first-year funding of $400,000 and the leveraging of funds, has resulted in the accumulation of more than $5.5 million for this year. Many of the leveraged funds, such as connections and maintenance by Metro, will continue in the future.

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University of Texas at El Paso Network Resources and Training Site

Principal Investigator: Dr. Michael A. Kolitsky
Department of Information Technology
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El Paso, TX 79968
Date of Original Award: 1995

INTRODUCTION

The NASA NRTS at the University of Texas at El Paso (UTEP), established through MU-SPIN, is striving to substantially increase and accelerate access to the Internet and the use of Internet resources by faculty and students in SMET departments in higher education. The program also includes a K–12 component for middle schools in the greater El Paso area. As part of the overall objective of the NRTS, UTEP is developing technologies and applications that can be disseminated in the educational arena to integrate the use of Internet resources in the classroom, increase computer and network literacy, enhance science, math, and engineering curricula, and provide access to NASA resources. These activities have the ultimate objective of inspiring and promoting students to pursue careers in high-technology industries. Future directions include promulgating current and future information and knowledge in a distance-learning environment.

Participants in an NRTS student workshop, held in the Multi-Media Teaching Learning Center.

RESEARCH ACCOMPLISHMENTS

The NRTS has increased network and Internet connectivity for a large number of SMET faculty at UTEP and also for the NRTS's K–12 outreach partners. In addition to providing basic network infrastructure and Internet connectivity, NRTS funding has enabled all SMET departments to establish a web presence that provides information about their respective schools, departments, faculty,

research, courses, and labs that are currently delivered via the Internet. The integration of standard curricula with electronic curricula that can be delivered via the Internet has spurred a wealth of technological development as part of faculty and student production. This project has greatly enhanced the active learning experience for those students and faculty who are involved in the production of web-delivered resources. The success of the NRTS has also provided a wide avenue onto the Infobahn for the dissemination of Internet technology and the promotion of science, math, and engineering for the faculty and students not directly involved with the project, whose interest in technology is peaked after being exposed to the NRTS's dissemination efforts. Current production efforts make possible the future delivery of educational content through the use of interactive video courseware and web-delivered courseware, which will utilize the resource base identified in the first year of the grant.

A videoconferencing session held at one of the hands-on training sessions, which attracted over 120 attendees from several types of learning institutions.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

The establishment of connectivity, along with the continuing development of technologies and applications that can be delivered via the Internet, supports the NRTS's goals of increasing the usage of electronically delivered information and curricula. Future uses of the information and the student/faculty resource base further enhance the widespread dissemination of electronically delivered courseware that can utilize a distance-learning environment for both "real-time" and asynchronous education. The NRTS's objectives also fulfill the goals of the National Information Infrastructure (NII) in the areas of research and education in institutions of higher learning, and they increase the use of NII resources in the K–12 arena.

BENEFITS TO SOCIETY

The NRTS has substantially increased the use of the Internet in the everyday lives of faculty and students who have been involved with the project at a minority institution. With the advent of the information age and the increasing emphasis on computer-mediated communication and information technologies, the NRTS's efforts have been the driving force behind the dissemination of the skills, techniques, and benefits derived from network and Internet connectivity. NRTS efforts in the educational arena are delivering and incorporating the knowledge base necessary for life in the 21st century in an equitable fashion.

STUDENT ACHIEVEMENTS

All students who worked on web site construction and maintenance are at the forefront of Internet technology. They have become the "experts" in their respective departments and, as such, have worked to educate and disseminate their knowledge of the Internet to faculty and other students. To view the quality of their work, go to http://www.utep.edu/nasa/smet.html and follow the links to each of the SMET departments.

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FACULTY AWARDS FOR RESEARCH

NASA's Faculty Awards for Research (FAR) program seeks to provide NASA with those resources necessary for mission completion while developing a diverse NASA-sponsored research community made up of institutions with significant underrepresented minority enrollments. The FAR program supports faculty-driven research at HBCUs and OMUs that is relevant to the NASA Strategic Enterprises as described in the NASA Strategic Plan. Participation in FAR is currently open to tenure-track faculty of HBCUs and OMUs that offer degrees in engineering, mathematics, or science disciplines.

As a result of participating in this program, Principal Investigators contribute directly to NASA research and support the development of disadvantaged and/or disabled student researchers. Opportunities for participation in the Agency's mainstream research expand as recipients' research capabilities are enhanced through interaction with NASA researchers and facilities. Additionally, the pool of disadvantaged and/or disabled students with research experience and interest in pursuing advanced degrees in the fields of science, engineering, and mathematics increases through faculty support.

During its 5th year, the FAR program funded 48 research projects (including 22 new projects) at 25 institutions: 10 HBCU's, 8 OMU's, and 7 other universities. The data that follow were obtained from 20 of the 26 projects that had been funded for at least 1 year.

This report summarizes the activities of these FAR during Summer 1995, and Academic Year 1995–1996 reporting period. During this period, 28 professional-level investigators were involved in the 20 research projects, including 23 faculty members and 5 research associates. A total of 83 students—including 45 undergraduate and 38 graduate students—participated in these research activities. The research accomplishments were documented in 22 refereed papers or book chapters that were published during this time period. Significantly, 17 students were authors or co-authors of these publications. An additional 12 papers or book chapters, including 13 student authors or co-authors, were accepted for publication during this period. The broader research community was informed of this work through 39 technical presentations given at national and international conferences, including 21 presentations given by students.

During FY 1996, the 20 reporting FAR projects were able to leverage their NASA MUREP expenditures ($1,964,184, not including $579,454 of student support) to an additional $1,844,700 in research support, $452,000 from other NASA programs, and $1,392,670 from other agencies.

An additional objective of the FAR program is to increase the number of disadvantaged and/or disabled students receiving mathematics, science, engineering, and technology research experience and entering careers in NASA-related fields. Forty-five of the 83 students (54 percent) participated at the bachelor's-degree level; 28 out of 83 (34 percent) participated at the master's-degree level; and 10 out of 83 (12 percent) participated at the doctoral degree level. Fifty-seven percent of the participating students were members of an underrepresented ethnic minority group.

Twenty-eight student participants obtained degrees during the reporting year: 14 bachelors degrees; 12 masters degrees; and 2 doctoral degrees. Sixty-eight percent of the graduates were members of an underrepresented ethnic minority group. Thirteen of the graduates were employed in NASA-related fields: 5 bachelors degree graduates and 8 masters degree graduates.

Seven of the 14 bachelor's degree graduates (50 percent) planned to pursue graduate degrees, while 5 of the 12 masters degree recipients planned to pursue doctoral degrees. In total, 86 percent of the students receiving degrees remained in the pipeline by continuing for the next degree, or by accepting employment in a NASA-related field.

Brief reports from the projects funded during Summer 1995, and Academic Year 1995–96, along with abstracts of the newly-funded projects, follow.

Ames Research Center (Reports)

Dynamics of Variable Mass Systems

Principal Investigator: Dr. Fidelis O. Eke
Department of Mechanical and Aeronautical Engineering
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Davis, CA 95616-8671
Date of Original Award: 1993

INTRODUCTION

The dynamic behavior of mechanical systems with continuously varying mass has been of special interest to scientists and engineers since the first half of the 20th century. Investigations of such systems have attracted most interest in the aerospace field, especially in the study and design of rockets. The anomalous coning behavior observed on a class of spinning, solid rocket-propelled spacecraft systems in the early 1980s was a dramatic reminder of the inadequacies in the current understanding of dynamics of variable mass systems. This research project focuses on the thorough examination of the effects of substantial mass variation on the dynamic behavior of various objects in space flight.

RESEARCH ACCOMPLISHMENTS

This past year, we have augmented our previous results on how the attitude motions of space vehicles can be affected by mass variation. We conducted an in-depth study of the free attitude motions of a rocket-type system that is initially a solid right cylinder and loses mass continuously as it moves around in space. The cylinder problem is very important and useful for several reasons. First, it models rocket-type systems in a simple enough way that the equations of motion become relatively tractable. Generally, space vehicles are designed to be more or less axisymmetric in shape, and a cylinder is in fact a good—albeit rough—approximation for such systems. Hence, a thorough study of the variable mass cylinder problem is a useful exercise, in that it provides a means of performing tractable analytical studies of rocket systems and can yield useful insight into the dynamic behavior of this class of variable mass systems.

Using the cylinder model, we examined the effects of substantial mass loss on the attitude dynamics of rockets for various mass-loss scenarios. We found that substantial mass loss does have a major effect on the attitude behavior of space systems—both quantitatively and qualitatively. For example, a spinner that would normally exhibit stable attitude motion can become unstable if it is subjected to continuous and substantial mass loss during its motion. Some of the results are shown in Fig. 1 and agree, at least qualitatively, with telemetry data obtained in the actual flight of a class of space vehicles.

In studying the effects of mass variation on the behavior of space vehicles, the system of interest can be assumed to comprise two phases at any given instant—a solid phase and a fluid phase. The results of Fig. 1 were obtained by

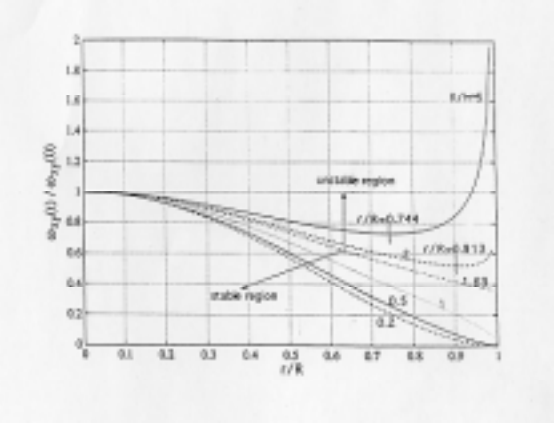

Figure 1 Transverse Angular Velocity for Radial Burn

ignoring the contributions of the fluid phase to the instantaneous inertia properties of the system. We also conducted another study that explored the impact of including fluid inertia in the analysis of the motion of the system. This was done by assigning a nonzero value to the ratio of the fluid density to that of the solid portion of the system. The equations of motion were then solved for the time histories of the system's angular velocity components, with density ratio as a parameter. In general, the fluid products of combustion were found to have attenuating effects on the transverse angular velocity components; however, fluid density was found to have no effect on the actual onset of instability.

NASA Enterprise Areas: Space Science, Human Exploration and Development of Space, and Mission to Planet Earth

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Monitoring Software Through Integrity Constraint

Principal Investigator: Dr. Ann Quiroz Gates
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Date of Original Award: 1995

INTRODUCTION

The rapid advancement of technology has created the demand for more complex systems that require deep and diverse applications knowledge. Building such systems requires expertise in domain-specific knowledge that could include areas such as flight control, navigation, and sensor processing, expertise in software-related knowledge (in areas such as operating systems, human-computer interface, object-oriented technology, and distributed systems), and an understanding of relevant social and legal factors. This exacerbates a longstanding problem in software engineering: managing conflicts in the requirements and communicating specialized knowledge to members of the development team who have varied levels of expertise. This research effort is addressing the above concerns through an approach called context monitoring—the use of integrity constraints to capture the conditions that data manipulated by the program must satisfy and the dynamic monitoring that verifies their enforcement by the program. The goals of the research are to develop a methodology for capturing knowledge about the data, the intended context in which the program will run, and other knowledge about the program through integrity constraints, to develop a language for integrity constraint specification, and to create a constraint satisfiability mechanism that verifies their enforcement during the program's execution.

RESEARCH ACCOMPLISHMENTS

After the first phase of the project, a methodology for eliciting constraints during the requirements stage of software development was completed, and a constraint satisfiability mechanism was implemented in the very high-level language, SequenceL. The next phase of research will concentrate on refining the existing methodology for requirements of constraint elicitation and extending it to include design and implementation constraint elicitation. The research for developing a constraint satisfiability mechanism for a mainstream language is in its early stages.

RELEVANCE TO NASA STRATEGIC ENTERPRISES AND BENEFITS TO SOCIETY

The research effort will result in a variety of tools: a tool that can be used to detect potential conflicts in the constraints; a tool that maintains links from the constraints to a project database and displays relevant information when a constraint violation occurs; and a software maintenance tool that can be used to determine the impact of change on a system with respect to the constraints. When completed, these tools can be used to improve the reliability and integrity of software. This research is relevant to areas in which large and/or complex computer systems are being developed, as well as in the processing and manipulation of large information systems.

STUDENT ACHIEVEMENTS

Francisco Fernandez, one of the undergraduate researchers funded by this project, was named outstanding undergraduate computer science student for his graduating class in the spring of 1996, and he received a full National Security Agency fellowship to attend graduate school.

NASA-funded students working in the Software Engineering Affinity Laboratory at the University of Texas at El Paso.

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Statistical Sensor Validation in Life Support Systems

Principal Investigator: Dr. Derrick K. Rollins
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Date of Original Award: 1993

INTRODUCTION
The basic objective of this project is to apply statistical methods for the improvement of modeling and data analysis to further the scientific progress of space closed-loop life support systems (CLLSS). This objective is specifically narrowed to three distinct subprojects. The first is the development of statistical techniques that validate and improve measured variables in the context of sensor redundancy in CLLSS. The second is the accurate empirical modeling of the human thermoregulatory response to exercise. Accomplishing this goal could lead to a better design of spacesuits and better monitoring of humans in space to predict and control demands for materials and energy. The final subproject is the determination of a method to obtain the best artificial neural network (ANN) model and to model the thermoregulatory system. Below, summaries are given for the progress of this work for Summer 1995 and Academic Year 1995–96.

RESEARCH ACCOMPLISHMENTS
We developed and evaluated two validation methods for cases of redundant sensors. Both methods show considerable promise in accuracy, with neither method consistently better than the other as determined by a fairly extensive Monte Carlo simulation study. Two measurement models are evaluated: one with random measurement bias and one with nonrandom measurement bias. Our next step is to determine the probabilistic properties of the methods and then to apply them to real data from a crop growth chamber at the Ames Research Center. After completion of this work, we will submit an article for publication. An M.S. statistics student is doing this research.

Significant research was also completed during this period in investigating model discrimination methods for ANN. This extensive simulation study evaluated the following techniques: the F test (FT); Akaike's Information Criterion (AIC); Mallows' Cp (MCp); Data Splitting (DS); Mean Squared Error (MSE); and Schwartz's Bayesian Criterion (SBC). The study concluded that the criteria used in DS were significantly affected by a change in the number of replications of input data or a change in the level of experimental error variance, as well as that these changes had little effect on any other technique. The overall performance of MSE in choosing the correct model was found to be worse than any other technique. MCp and AIC had similar results, but did not perform as well as FT with alpha = 0.01 or Mean Squared Prediction Error, which is a DS criterion. SBC performed better than any other technique in most situations, but performed quite poorly in a few cases. This work resulted in an M.S. thesis in statistics, and it has been submitted for publication.

Finally, during this period we were able to complete a computer program that theoretically and semi-empirically models human thermoregulatory response to exercise. This part of the research was completed for the final stage, which involves using this program to obtain critical knowledge about the best way to empirically model the thermoregulatory systems for individuals using ANN. An M.S. student in statistics is performing this research.

BENEFITS TO SOCIETY
The impact that this work can have on the average citizen is a general improvement in the modeling and data analysis of physical systems. This will in turn reduce variability, which will provide greater reliability, better quality, lower environmental contamination, and lower energy consumption of chemical processes, plants, and equipment.

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Ames Research Center (Abstract)

Theoretical and Observational Studies of Solar and Extra-Solar Planetary Atmospheres

Principal Investigator: Dr. Mark S. Marley
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Date of Original Award: 1996

ABSTRACT OF PROPOSED RESEARCH
The newly detected Jovian planets orbiting four stars offer an exciting opportunity to better understand planets and planetary formation in other solar systems. To connect observations of total luminosity and high-resolution spec-

tra of objects such as the brown dwarf G1229B to physical characteristics such as age and mass requires the application of planetary atmospheric models. To understand the character and evolution of the newly described planets, the deposition of stellar energy into their atmospheres must be modeled. This proposal will apply a radiative-convective equilibrium planetary atmospheric model developed for the Jovian planets to these newly discovered objects. This research will help constrain the properties of the newly discovered objects and facilitate the search for more extra-solar planets.

Observations of stellar occultations by planets in our own solar system provide unique information that cannot be obtained by other remote-sensing observations. This proposal will employ a remarkable new camera system on the Apache Point Observatory 3.5-meter telescope to obtain very-high-time-resolution infrared images of stellar occultations by Jupiter, Uranus, and Pluto. Such observations will provide new insight about the temperature structure and small fluctuations of these atmospheres and the ring system of Uranus.

This work will provide opportunity for at least two New Mexico State University minority undergraduate students to study planets around other stars and to work with a state-of-the-art infrared camera. The long-term mentoring relationship and financial opportunity will support these students as they obtain bachelor's degrees in the physical sciences.

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Dryden Flight Research Center (Reports)

Chemically Derived Dense Alumina-Zirconia Composites for Improved Mechanical and Wear Erosion Properties

Principal Investigator: Dr. Lebone T. Moeti
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Atlanta, GA 30314
Date of Original Award: 1994

INTRODUCTION

The development of new materials with improved properties, such as strength, toughness, and wear resistance for advanced structural applications (such as engine components), will be crucial in meeting emerging high-technology aerospace applications. Zirconia-toughened alumina (ZTA) has the potential improvement in toughness and strength when compared to pure alumina to meet these technology requirements. The main objective in this project is to examine factors such as particle size, particle size distribution, and the nature of the polymorph to determine how they contribute to the toughening mechanisms and strength enhancement in ZTAs. These factors will be modified by the processing techniques used in the fabrication of ZTA ceramics.

RESEARCH ACCOMPLISHMENTS

Our main accomplishment was establishing the synthesis for the preparation of high-purity ZTAs. In this research program, high-purity starting materials such as aluminum-, zirconium-, and yttrium-metal alkoxides were used to prepare ZTAs. High-purity starting materials will yield ZTA ceramics free of impurities that could migrate to grain boundaries and thereby lower strength and toughness or may possibly lead to glass formers at the grain boundaries. Additional accomplishments were the synthesis of ZTA precursors by using aluminum-tri-sec-butoxide, zirconium butoxide, and yttrium butoxide. We synthesized the yttrium butoxide by performing an alcohol exchange of yttrium isopropoxide in butanol. We are now in the process of conducting calcining and sintering studies in the preparation of the final ZTA ceramic. Synthesis conditions are being varied, and their effects on the final properties of the ZTA will be established.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

The ZTA ceramics being developed with improved strength and toughness are crucial to the materials program of NASA's Aeronautics and Space Transportation Technology Enterprise, because they will meet the requirements of high-temperature engine components. The utility of such materials will be realized in engine parts for the National Aerospace Plane (NASP). In addition, high-temperature component parts fabricated from materials such as ZTA will be used in commercial aviation to improve fuel efficiency at higher operating temperatures.

STUDENT ACHIEVEMENTS

Most of the research conducted in this project has been performed by a master's student in chemistry and has resulted in one national conference presentation and one refereed paper.

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Development of an Ultrasonic and Fabry-Perot Interferometer System for Nondestructive Inspection of Aging Aircraft Structures

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Date of Original Award: 1994

Report not submitted.

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Goddard Space Flight Center (Reports)

Estimation of Ocean Primary Productivity using In-situ Fluorescence and SeaWiFS

Principal Investigator: Dr. Jose M. Lopez
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Date of Original Award: 1994

INTRODUCTION
A major goal of optical oceanography in the context of NASA's Mission to Planet Earth is the estimation of phytoplankton primary production. For this task, the Earth Observing System's Sea-viewing Wide Field-of-view Sensor (SeaWiFS) remotely sensed data needs to be coupled with improved measurements of photosynthesis. The proposed research integrates remote sensing of ocean color using the SeaWiFS and in-situ active fluorescence measurements of photosynthesis for an improved estimation of ocean primary productivity.

RESEARCH ACCOMPLISHMENTS
We have modeled production by micro-algae in the ocean, based on determinations of phytoplankton community photosynthetic parameters. These are generated from photosynthesis-irradiance (P vs. E) curves in experiments with radio-carbon tracers in discrete water samples. The samples were obtained from the upper 100 meters in the Caribbean Sea using clean techniques.

To date, the Principal Investigator and student trainees have conducted P vs. E curves on already scheduled monthly cruises of other NASA-funded research projects, on which this Principal Investigator is also a co-investigator. Measurements made by collaborators from the deployment of other instrumentation (CTD, Underwater Radiometer, and Flash Fluorometer) and hydrocasts provide the physical, chemical, and biological context for the P vs. E measurements.

RELEVANCE TO NASA STRATEGIC ENTERPRISES AND BENEFITS TO SOCIETY
This work is contributing to the understanding of the magnitude of the role of the ocean in incorporating CO_2 from the atmosphere and thus reducing the greenhouse effect. Other uses of this research are in the evaluation of discharges of excessive amounts of plant nutrients that reach the marine environment and also in the evaluation of the potential for fisheries production.

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Experimental and Theoretical Studies of Capillary-Pumped Loop Heat Pipes

Principal Investigator: Dr. Nsima T. Obot
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Date of Original Award: 1993

INTRODUCTION

The capillary-pumped loop (CPL) heat pipe is a two-phase flow device that is capable of transferring large amounts of energy over long distances. The circulation of the working fluid results from capillary forces developed in the wicking material. Although the potential of the CPL for space applications has been demonstrated in ground

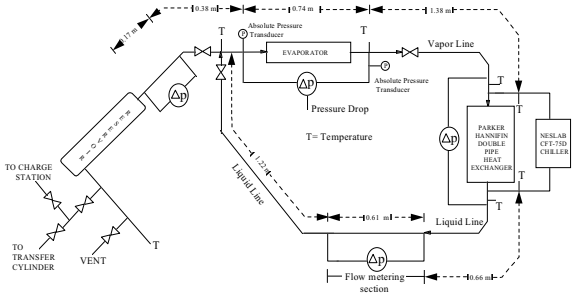

Figure 1 Schematic of CPL Test Facility

and flight tests, there is the need to address fundamental thermal and fluid issues. Accordingly, the primary objective of this work is to carry out a consistent experimental study of the CPL with ammonia as the working fluid for a range of geometric and operating conditions.

RESEARCH ACCOMPLISHMENTS

A schematic of the test facility designed and built for the experimental studies is shown in Fig. 1. The main components include a two-phase reservoir, an evaporator pump, a condensing section consisting of a Neslab Model CFT-75D chiller and a Parker Hannifin dual heat transfer coil, and a liquid ammonia metering section. Heating of the evaporator was accomplished with insulated nichrome wires, located axially in 0.8-mm grooves machined on the outside surface of the aluminum, using a DC power supply. The evaporator surface temperatures were measured with 16 chromel-constantan thermocouples (not shown in Fig. 1), which were installed at four locations along the

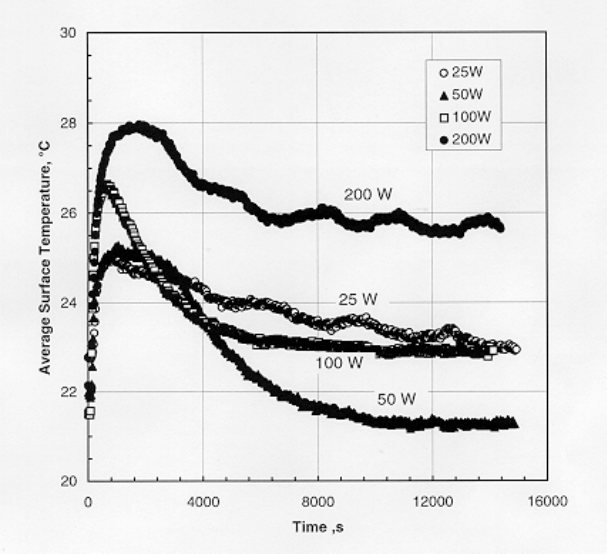

Figure 2 Evaporator averages temperature versus time

0.6-m length of the evaporator. Provisions were made for temperature, differential, and absolute pressure measurements at strategic locations.

Typical variation of the evaporator average surface temperature with time is shown in Fig. 2. These results were obtained with uniform heating of the evaporator. It is evident that the differences in the average surface temperature among the four sets of data are no more than 4°C. Corrections were not applied to these results to account for the differences in the ammonia saturation temperature or the room temperature; both are inseparably connected. Experiments were also carried out to determine the effect of nonuniform heating of the evaporator for a range of total electrical power input. Although nonuniform heating resulted in significant axial and circumferential temperature variations, the average surface temperatures were within 2°C of the values obtained with uniform heating. One of the attractive features of the CPL is that the average surface temperature of the evaporator does not vary greatly with the applied heat load.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

This work complements ongoing research efforts on space-based thermal control and management. Aside from the use of the recommended working fluid for space applications, the evaporator pump used in the study is a replicate of that considered for possible application on the Earth Observing System (EOS).

BENEFITS TO SOCIETY

The CPL is an adaptation of the conventional heat pipe that is used for cooling electronic components, computers,

and energy-conservation equipment. The results of this research should lead to improvements in the design of these and other heat-pipe-based systems.

STUDENT ACHIEVEMENTS
Two undergraduate research assistants (Joy Felton and Andrea Shelton) were awarded the 1996 GEM (National Consortium for Graduate Degrees for Minorities in Engineering and Science) Fellowships for graduate studies in chemical engineering. Karrin Mayfield (with a B.S. in chemistry from Norfolk State University) will complete her M.S. in Engineering in 1997.

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Goddard Space Flight Center (Abstracts)

Exploitation of Properties of Aggregated Molecules for Optical Device Applications

Principal Investigator: Dr. Daniel L. Akins
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Date of Original Award: 1996

ABSTRACT OF PROPOSED RESEARCH:
This proposal addresses spectroscopic studies of properties of aggregated molecules absorbed onto surfaces or dissolved in homogenous solution, as well as the exploitation of such systems for technological applications. The Principal Investigator, specifically, proposes to expand basic research investigations currently pursued in his laboratory that provide fundamental molecular information about aggregated molecules, such as structural information implicit in measured dipole-dipole interaction energies, and the influence of the intermolecular structure of the aggregate on the intermolecular structure and dynamics of the intercalated monomeric species.

Moreover, the Principal Investigator proposes to exploit the properties of aggregated molecules to: (1) develop a superradiant nanometer (or nanoscale) light source for near-field scanning optical microscopy, used to optically image very small sample areas; (2) formulate a coating composed of aggregated molecules that allows remote detection, as for example in search-and-rescue, through luminescence that is monochromatic and superradiant (this system involving aggregated molecules would have a different format than that of "LaserPaint™"); and (3) develop applications (under the general heading of fluorescence lifetime variation sensors) for an aggregated molecular system whose time-dependent emission (specifically, emission lifetime) depends on the excitation wavelength, and has at least two possible emission rates, while the optical emission spectrum remains unchanged with excitation wavelength.

These research efforts fall under the Strategic Enterprise thrust of Mission to Planet Earth, with overlap to efforts aimed at using optical techniques for remote sensing and search-and-rescue.

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Formal Foundations of Agents

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Date of Original Award: 1996

ABSTRACT OF PROPOSED RESEARCH
The first objective of the proposed effort is to select and develop the appropriate formalisms for specifying agent systems and to develop a methodology for the use of these formalisms. The agent systems of interest will conform to the AGENTS model of distributed agents being developed at the Goddard Space Flight Center.

Test cases for the formalisms and methodology will be taken from Goddard's intended applications of its model. The scope of the formalisms will cover agent speech acts, multi-agent reasoning and action, and agent knowledge and obligation. Formalisms to be considered include speech act theory, temporal, epistemic, and deontic logics, formal ontology, and nonmonotonic logics. A major output will be a user's document presenting the formalisms and methodology.

Subsequent objectives will extend our formal approach to Goddard's agent communication language and features of agent systems useful to Goddard. Semantics will be provided for certain language constructs, and algorithms, inference methods, or protocols will be developed for select system features.

A general object to be pursued throughout the effort is to develop African American student researchers in computer science. This will be realized primarily via close research mentoring.

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Basic Research in Atomic, Molecular, and Optical Physics in Support of NASA Strategic Enterprises

Principal Investigator: Dr. Kenneth A. Hardy
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Date of Original Award: 1996

ABSTRACT OF PROPOSED RESEARCH
The proposed program will study the interactions of atomic and molecular species common in the upper atmosphere of the Earth and in the Space Shuttle glow region.

Current studies of metastable atom interactions with atoms and molecules common in the glow region surrounding the Space Shuttle are under way. One item of interest to NASA, atomic oxygen, has several metastable states. Dissociative recombination reactions of rare gas diatomic ions will also be studied. This reaction is the primary method for electron removal from plasmas formed in gas discharges. These studies have resulted in the identification of previously unknown final states of the reactions. Studies are also being conducted with laser-cooled beams of metastable atoms.

Further studies will concentrate on the understanding of atomic and molecular interactions at low relative velocities and the understanding of the interaction of light with atomic beams. An understanding of cool atom collisions will eventually lead to better time standards. A series of experiments with cold atom traps may be a candidate for the Space Shuttle in the future, as the gravitational interaction in Earth-bound laboratories eventually empties cool atom traps after the light is extinguished. These traps would have a longer lifetime in a gravity-free environment.

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Effects of Aerosols and Cloud Interactions on UV, PAR and Crop Yields

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Date of Original Award: 1996

ABSTRACT OF PROPOSED RESEARCH
Over a 3-year period, the proposed program will assess direct and indirect effects of anthropogenically generated aerosols on surface fluxes of ultraviolet radiation in the UVA (320–400 nm), UVB (280–320 nm), and PAR (photosynthetically active radiation, 400–700 nm) wavelength regions. Studies will include the use of three-dimensional, model-generated sulfate aerosol fields resulting from emission estimates. Estimates of indirect effects will include responses of tropospheric and stratospheric ozone to aerosol-induced radiative changes. The indirect effects of aerosols on cloud optical properties will be parameterized based on results from separate modeling studies and observations. Finally, studies of the sensitivity of crops to spectral radiative changes will be used to estimate the agricultural and ecological impacts resulting from increased aerosol abundances.

Initial studies will incorporate zonally averaged, seasonally varying, anthropogenic aerosol distributions into a two-dimensional chemistry-radiation-dynamic (CRD) model for the calculation of the UVA, UVB, and PAR surface fluxes. Major results will include seasonal limits of the aerosol-induced variation in these radiation fluxes for various latitude regions. Additional aerosol scenarios will include zonal averages taken from observations and scenarios that reflect the magnitude of zonal inhomogeneities. Final studies will use limited 3-dimensional chemical-radiation-transport model analyses. Coupling between changes in aerosol loading and ozone chemistry, via photolysis rates and temperature changes, will be investigated.

Estimated effects of increased aerosols on cloud reflectivities, via changes in particle number densities and size distributions, will be included. Current models and experimental determinations of UV and PAR radiation effects on particular crop yields will be used to determine whether the aerosol scenarios considered have meaningful consequences for crop yields.

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Jet Propulsion Laboratory (Reports)

Computational Field Simulation on Massively Parallel Computers

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Date of Original Award: 1993

INTRODUCTION

The goal of this research is to develop computational methods for solving large, sparse, irregular systems on massively parallel computers. Such problems may arise in physics, mechanical engineering, civil engineering, or electrical engineering as a result of the discretization of the governing differential equations. The computational methods are being developed for portability and ease of use.

RESEARCH ACCOMPLISHMENTS

We have developed computer codes for solving problems in semiconductor device modeling, electromagnetic scattering, and electrostatic field analysis, using the Cray T3D at the Jet Propulsion Laboratory. The size of the problems that are being solved could not be attempted on a conventional scaler or vector computer.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

The research performed in this project has direct relevance to the Earth sciences. More specifically, remote sensing using satellites to map different physical parameters on the planet is an inverse problem. Electromagnetic energy in the microwave bands is used to do much of the remote sensing, so that the inverse problem requires robust electromagnetic forward solvers. However, the forward problem is large enough to be classified as a "grand challenge," requiring the use of massive parallelism to arrive at a solution. The algorithms being developed in this research will be directly applicable to the remote-sensing problem. Other areas that may benefit include computational fluid dynamics and structural analysis for large-scale structures requiring the use of a massively parallel computer.

BENEFITS TO SOCIETY

The amount of work per unit-time that can be done by a single microprocessor has been doubling every 2 years. However, we are fast approaching the time when the pace at which computational power can continue to increase, for the microprocessor will begin to decrease because of physical limitations. Some estimates place that point in the next 10 to 15 years. The way around this dilemma is by using multiple processors to attack a single problem. However, the use of multiple processors requires that communication take place as the solution proceeds. Therefore, existing computational solutions that were developed for a traditional single processor computer must be completely reworked to take maximum advantage of the multiple processors. Solving the software problems associated with parallel computing will become increasingly important as both industry and government come to rely on computational modeling rather than the more expensive experimental lab work for design and development.

STUDENT ACHIEVEMENTS

Four students have been involved in this research, with two of them receiving MSEE degrees in 1996. Jay Martinez received his MSEE in May 1996 and is now working in industry. William Dearholt received his MSEE in December 1996 and is now pursing his Ph.D. in the same area. Charles Salazar is currently finishing his MSEE and expects to graduate in May 1997. Gary Hennigan is working toward a Ph.D. degree and expects to finish in December 1997.

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Analysis and Modeling of Venus Gravity and Topography Data from the Magellan Mission

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Date of Original Award: 1993

INTRODUCTION

The Magellan mission to the planet Venus, which started mapping the surface on September 15, 1990, has already yielded a wealth of new information. After one sampling cycle, the on-board Synthetic Aperture Radar (SAR) had mapped the majority of the planet's surface, with the remainder to be mapped in subsequent cycles extended to 1995. The purpose of this project is to conduct a study of these new data sets to better understand the mechanical behavior of Venus' lithosphere and the dynamics of Venus' mantle as it relates to the lithosphere. The data sets being used in this study include surface topography from altimetry and free-air gravity anomalies.

The ongoing research has three major objectives: to obtain values of the admittance (ratio of gravity to topography in the wave number domain) for a variety of surface features (this analysis will help to constrain the apparent depths of compensation [ADCs] for the different features); to analyze the admittance to obtain lateral lithospheric strength variations; and to explain the ADCs and the lithospheric strength variations in terms of models of mantle dynamics. The part of the project to be worked on in this cycle includes the following:

- Produce a suite of plots of the observed admittance function for a variety of features on the surface of Venus;
- Compare the observed admittance to theoretical admittance functions derived from models of both elastic plate surface loading and sub-surface loading;
- Obtain estimates of the effective elastic thickness (Te) for the various features;
- Produce a surface map of the lateral lithospheric strength variations from the values of Te; examine the spatial distribution of the observed admittance function for the various features;
- Determine whether a correlation exists between the admittance at a specific wave number and the mean latitude of the surface feature (this may offer some clues as to the platform of thermal convection in Venus' mantle).

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High Tc Bolometer Development

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Date of Original Award: 1994

The responsivity of a bolometer is inversely proportional to the thermal conductance (Tc) between the thermally isolated region, which is sensitive to radiation and the heat-sink to which it is attached. This responsivity could be made extremely high by using thin, free-standing membranes with very low thermal conductance. By making these structures very small, a fast thermal response can also be achieved.

To obtain epitaxial superconductor Y_{123} films on thin membranes, we will have grown the following structures: Y_{123}/(MgO or YSZ)/(Si or NaCl), $Y_{123}/SrTiO_3/MgO/Si$, and $Y_{123}/SrTiO_3$/NaCl. In these structures, membranes will be fabricated by bulk chemical micromachining of the substrate, where the buffer layer will act as an etch-stop layer. Si and NaCl are utilized as substrates because of their micromachining capabilities. NaCl is, of course, soluble in water.

The measurement of transport properties of these films is the focus of this effort. Critical temperature, transition width, and critical current density are usually less favorable in large mismatched systems (such as Y_{123}/MgO or Y_{123} /YSZ), as compared to lattice-matched systems (such as $Y_{123}/SrTiO_3$ or Y_{123}/LaAlO). The effect of growth parameters in these structures on transport properties will be investigated.

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Jet Propulsion Laboratory (Abstracts)

Multilayer Thin Film Capacitors for High Performance Power Applications

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Date of Original Award: 1996

ABSTRACT OF PROPOSED PROGRAM
The objective of the proposed task is the development of multilayer thin film, high-energy-density, low-mass capacitor structures for high-performance power and storage applications, which contain no liquid electrolytes and can be manufactured at acceptable costs. The aim is for order of magnitude, rather than incremental, improvement in dielectric strength and capacitance.

The dielectric materials of choice are silicon-aluminum-oxynitride (sialon), diamond, and cubic boron nitride. Earlier work supports the efficacy of these materials, alone or in combination within these systems, making them particularly attractive from a property-tailoring point of view.

Unique advantages directly result from the proposed dielectrics, which are radiation hard and display the highest known values of thermal conductivity, reducing thermal breakdown. The proposed processing system, magnetron sputtering, needs no major development and is fully adaptable to device manufacturing.

The characterization of deposition substrates, electrode surfaces, and resultant thin films in terms of structural and physical properties forms an essential part of the proposed investigation.

This research task will be coordinated with NASA efforts and personnel engaged in similar space technology and scientific research missions, specifically at the Jet Propulsion Laboratory. The deliverables from this effort will be operational capacitor structures and a proposal for a manufacturing system.

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Fault-Tolerant and Self-Checking Logic System Design

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Date of Original Award: 1996

ABSTRACT OF PROPOSED PROGRAM
The design of fault-tolerant logic systems requires much original work to be done in the areas of on-line error detection and novel design techniques for masking errors. The main thrust of this research project is to develop techniques that will guarantee logic systems that are error-free, easily maintainable, and safe; only minimal post-design modifications will be necessary to enhance the above mentioned features. The proposed research will consist of four tasks.

The first task will be to develop a technique for correct state transitions, even in the presence of a single bit transient error in a state register. This task will be completed within 12 months.

The second task will address automatic synthesis of self-checking logic circuits directly from their specifications. The netlist of the original circuit will be represented by using the Ordered Binary Decision Diagram (OBDD). The OBDD will then be modified such that the circuit's behavior is encoded. The netlist resulting from the modified OBDD will correspond to the self-checking version of the original circuit. This task is expected to be completed within 8 months.

The third task will focus on developing techniques so that a single logic fault in the circuit will result in predictable erroneous output bits. Several single-error-correcting/all-unidirectional-error-detecting techniques will be evaluated, and a scheme that can perform single-error correction with the least amount of circuit overhead will be developed. This task will be completed within 8 months.

The final task will concentrate on developing a hardware-based system for emulating a target fault-tolerant design and verifying its behavior. A fault injection mechanism will also be incorporated into the emulation system so that error detection and recovery in a target system can be evaluated. This task is expected to be completed within 8 months.

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Johnson Space Center (Reports)

Optimization, Fuzzy Adaptive Control and Intelligent Autonomous Space Exploration

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Date of Original Award: 1993

INTRODUCTION

Our objective with this research project is to investigate the possibility of applying a fuzzy-neuro adaptive controller, which we have recently developed in our laboratory, to a number of ongoing research activities at NASA. These include the efficient application of fuzzy logic, neural networks, and optimization to autonomous orbital operations at the Johnson Space Center (JSC) and specifically to vehicle health maintenance (environmental health), the control of tethered satellites, the control of spacecraft docking, and a more reliable interpretation of sensor data. We envision possible improvements and modifications to certain aspects of our controller prior to wholesale application.

RESEARCH ACCOMPLISHMENTS

In the first year, our work focused on language modifications, so that the controller can work on platforms that are compatible with those used by various researchers, including our oversight group, the Software Technology Group at JSC. Specifically, it has been reconfigured to operate on UNIX, DOS, and Macintosh platforms using Pascal and C/C++. The implementation of this does have an effect on learned control policy. The controller was then exercised on a prototypical problem of interest to NASA, namely the Tethered Satellite System retrieval problem. The controller performed satisfactorily in these experiments, in that it learned to retrieve the satellite from 100 km to almost 10 km before failure. The controller also learned the characteristic of optimal control, namely the "fishing motion" of sending the satellite out and then reeling it back in.

In the second year, our research focused on improvements in the performance of the controller, with particular attention paid to the controller's learning subsystem. Specifically, we extended the state of knowledge in fuzzy dynamic programming, fuzzy clustering techniques, and other dynamic programming-like methods. These are being used to improve state information and the efficiency of the reinforcement learning neural networks. In this regard, we highlight the development of a new fuzzy criterion clustering model that uses the concept of a fuzzy prototype as opposed to a crisp prototype. This method has been shown to overcome the effect of noise points, and is an effective clustering method. Its advantages over existing clustering techniques include the intrinsic property of not being distance- and other metric-dependent. Next, we developed the new technique of fuzzy criterion dynamic programming for multi-criteria decision-making and outlined its theoretical properties.

Our next task was concerned with an important aspect of fuzzy control; optimal defuzzification is related to model reference control and fuzzy optimal control. Using the methods developed, we can stabilize the system and optimize the performance of the controller with regard to a specific performance measure. This is important in view of the critical role played by stability in NASA's control activities.

Finally, the controller was modified to learn multiple input/multiple output (MIMO) control systems, and TD and Q-learning algorithms were thoroughly tested under various conditions on the application problems. The utility of this task relates to the presence of MIMO systems in complex problems of the genre encountered in NASA's activities.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

Our controller is now more intelligent than a number of existing controllers and can therefore be applied to a gamut of problems of interest to NASA, which have been addressed up to now by a solo application of fuzzy control theoretical methods. Our fuzzy clustering algorithms can be utilized in the clustering and analysis of sensor data obtained in space missions.

BENEFITS TO SOCIETY

This controller and its ongoing improvements can be used in many operations of interest to society, including intelligent manufacturing, message routing in communications networks, and traffic control, where standard tools are now employed.

STUDENT ACHIEVEMENTS
Students have been trained in the art and science of conference paper preparation and presentation. Students have been co-authors on two refereed journal articles and seven papers in refereed conference proceedings. Two of these students are scheduled to complete their doctorates in engineering sometime in 1997, while a third, an African American female, is now pursuing a master's degree in engineering.

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A Supervisory Controlled Telerobotic System

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No report submitted.

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Cellular Response to Hypogravity and Hypergravity Stress

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Date of Original Award: 1995

INTRODUCTION
Understanding the underlying cellular mechanism(s) that are responsible for the vascular changes found in animals and humans on space flights is a primary goal of the Life Sciences program of NASA. Achieving this goal is a necessity for the development of interventions that allow for continued and long-term manned space flights. A step in reaching this overall goal is ground-based studies that investigate the cellular changes (and the molecular mechanism(s) responsible) that are induced by altered gravitational fields.

RESEARCH GOALS
Ground-based studies utilizing cultured vascular smooth muscle cells (SMC) will provide the initial insight into possible mechanisms by which the space environment may alter vascular cell growth and behavior. The specific aims of the proposed research are to: evaluate whether changes in SMC proliferation and migration induced by different gravitational fields are coupled to the expression of autocrine growth and migration factors (such as, cmyc, TGFb, FGF, and galaptin), using antisense oligonucleotides to the mRNA for these substances; assess whether simulated microgravity and/or hypergravity will alter the expression of these autocrine growth and migration factors by SMC; and investigate possible signal transduction mechanisms that may be involved in gravity-induced cellular changes. The overall goals of the research proposed are to provide an understanding of the underlying mechanism by which changes in gravity alter cellular behavior and function, as well as to provide information useful to understanding the impact of microgravity on wound healing. The proposal plans to support the research training of one undergraduate student.

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Johnson Space Center (Abstracts)

Basic Studies of CdTe Solar Cells

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ABSTRACT OF PROPOSED RESEARCH
Novel characterization techniques incorporating spatial resolution will be developed and applied to CdTe/CdS solar cells in an effort to improve their conversation efficiencies in space and terrestrial applications. These novel techniques will generate maps of internal quantum efficiency (IQE), open circuit voltage (Voc), and lumines-

cence, providing detailed feedback on the effects of varying processing and design parameters on cell performance. This feedback will make us better able to fine-tune the cell designs and the processing parameters so that more efficient solar cells can be produced.

IQE measurements will be performed in the traditional manner, but will be repeated across the area of the cell. Voc maps will be generated by non-destructively measuring the surface potential under one-sun illumination, using a Kelvin probe. Photoluminescence and electroluminescence spectra will be observed using a charged coupled device camera-based imaging system with near-infrared sensitivity.

The IQE maps return information about material quality and device structure, the Voc maps provide feedback on junction quality, and the luminescence data help quantify material quality. These maps may be generated more than once during a process run, and they can be overlaid to search for correlations. These data will be part of an expanding knowledge base, which will be used to vary cell design and processing step parameters in a scientific way. The constant iteration of design, fabrication, and characterization will have better direction and should lead to higher cell conversion efficiencies.

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Kennedy Space Center (Reports)

Utilization of the Shop Floor Control Database: A Framework for Modeling Shuttle Processing Operations

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Date of Original Award: 1994

INTRODUCTION

This effort seeks to utilize the Shop Floor Control/Data Collection (SFC/DC) for modeling activities related to the assembly of the Space Transportation System (STS). We have proposed the Shop floor Modeling, Analysis, and Reporting Tool (SMART) framework, which relies on

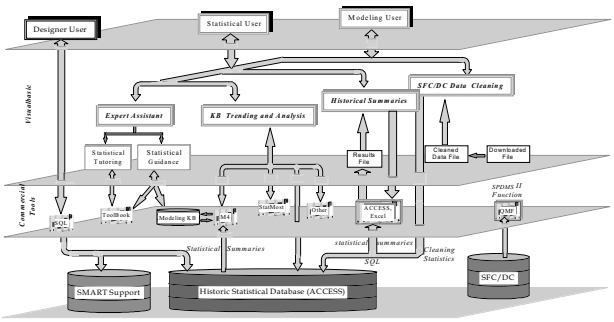

Figure 1 SMART Modules

knowledge derived from the SFC/DC data as well as on other operational procedures. Derived knowledge will become part of a knowledge base managed through M4, a commercial off-the-shelf expert system shell, whereas operational characteristics are part of a relational database managed through ACCESS, Microsoft's relational database management system.

RESEARCH ACCOMPLISHMENTS

Figure 1 depicts the various modules of SMART. It collects statistical information regarding work time, delay duration, and other historical summaries of relevance for future inferential analysis. A knowledge base trending and analysis module will utilize data-mining techniques to synthesize trends of certain measures of interest. Studies of the SFC/DC data have yielded rules that are being used to ascertain whether a record is complete and statistically useful. Various statistical models have been (or are being) added to SMART. An autonomous statistical interpreter is being designed for inclusion as part of the expert assistant module. A statistical tutorial is being developed. Testing of the prototype will begin in the spring of 1997.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

This effort supports NASA's Space Transportation System (STS). By understanding what actually happens on the assembly floor, we will be able to identify means to improve the various processes used to launch the STS.

BENEFITS TO SOCIETY

This effort will provide the means to identify how to improve the STS assembly processes, so as to improve process quality and reliability while maintaining budget constraints. In addition, this effort is allowing several students to learn and develop their creativity, their sense of pride in the Nation's space program, and their professionalism. These students are bound to become exemplary leaders in our society.

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Kennedy Space Center (Abstracts)

Surfactant/Supercritical Fluid Cleaning of Contaminated Substrates

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Date of Original Award: 1996

ABSTRACT OF PROPOSED RESEARCH

Chlorofluorocarbons (CFCs) and halogenated hydrocarbon solvents have been the solvents of choice to "degrease" and otherwise clean precision metal parts to allow for proper functioning. Recent regulations, however, have rendered most of these solvents unacceptable for these purposes. New processes that are being used or which have been proposed to replace these solvents usually either fail to remove water-soluble contaminants or produce significant aqueous wastes.

In this work, a new method for cleaning surfaces will be investigated. Solubility of typical contaminants, such as lubricating greases and phosphatizing bath residues, will be studied in several surfactant/supercritical fluid solutions. The effect of temperature, pressure, and the composition of the cleaning mixture on the solubility of oily, polar, and ionic contaminants will be investigated. A reverse micellar solution in a supercritical light hydrocarbon solvent will be used to clean samples of industrial wastes.

A reverse micellar solution is one where water is dissolved into a nonpolar solvent with the aid of a surfactant. The solution will be capable of dissolving both water-soluble and oil-soluble contaminants. Once the contaminants have been dissolved into the solution, they will be separated from the light hydrocarbon and precipitated by a relatively small pressure drop, and the supercritical solvent will be available for recycle and reuse.

The process will be compared to the efficacy of supercritical carbon dioxide ($CO_{2)}$ cleaning by attempting to clean the same types of substrates and machining wastes with the same contaminants using supercritical $CO_{2.}$ It is anticipated that the supercritical CO_2 process will not be capable of removing ionic residues.

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Langley Research Center (Reports)

Constitutive Modeling and Testing of Polymer Matrix Composites Incorporating Physical Aging at Elevated Temperatures

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Date of Original Award: 1994

INTRODUCTION

The next generation of military and commercial aircraft requires applications for high-strength, low-weight structural components that can safely be subjected to elevated temperatures. The Hybrid Titanium Composite Laminate (HTCL) is a material system that merits attention, because of its capability to operate in structures at higher temperatures. In this system, thin plies of titanium are adhesively laminated together using a high-temperature resin with high-modulus fibers included in the bondline. A schematic of such a laminate is shown in Figure 1.

This study investigates the laminated/hybrid technology as applied to high-temperature titanium alloys and a graphite fiber-reinforced, high-temperature thermoplastic polyimide adhesive. Four unidirectional HTCL systems

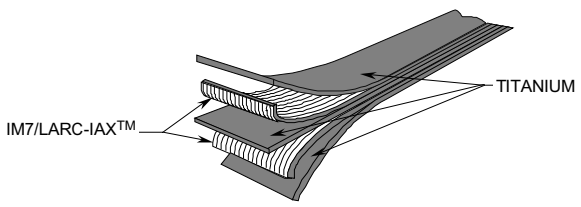

Figure 1 Schematic of the Hybrid Titanium Composite Laminate (HTCL)

were fabricated and mechanically tested with different titanium alloys and titanium layer thickness. An analytical laminate analysis was also performed, to predict the HTCL strength and load-deformation response based on the strengths and stiffness of its laminate.

RESEARCH ACCOMPLISHMENTS

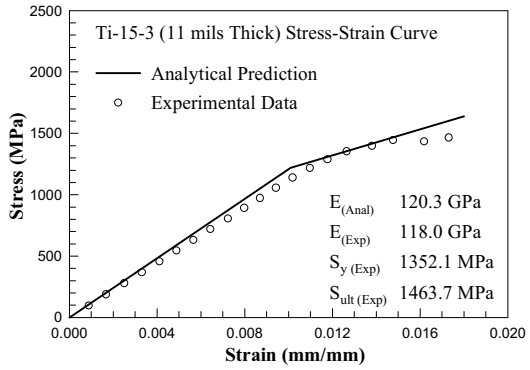

Figure 2 The stress-strain response of the 11 mils thick Titanium Ti-15-3 specimens.

The experiments show that the titanium layer in these HTCL systems influences the mechanical properties. Higher yield strength in the titanium alloys results in HTCL systems with greater ultimate strength. However, stiffer titanium alloys did not result in an HTCL with a higher elastic modulus. The yield strength of the titanium layer had no significant effect on the yield strength of the HTCL. If systems with higher strength-to-weight ratios are of primary concern, as in applications for future high-speed aircraft, HTCL systems that are fabricated with many thinner titanium plies show improvement over systems with fewer, thicker titanium plies.

Good agreement was achieved between the analytical laminate analysis performed in this study and experimental values obtained for the Young's modulus and the strength of HTCL systems, as shown in Figure 2. The stress-strain curves and the stress level at which the titanium layers fail are predicted using classical lamination theory and the Tsai-Hill failure criterion. The thermal residual stresses from the curing cycle have been accounted for in the predictions. It was found that the nonlinear behavior before laminate failure did not significantly affect the analytical predictions, and thus the use of an elastic-plastic laminate analysis is not required to predict the strength from constituent properties.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

The High-Speed Civil Transport, envisioned to have a lifetime of more than 60,000 flight hours at operating temperatures near 188°C and to travel at speeds of Mach 2, is the impetus for intensive design and development studies at NASA and major airframe developers. The results of this work are needed to demonstrate that these systems will be useful in this next generation of high-speed aircraft.

STUDENT ACHIEVEMENTS

Two undergraduate students supported by this grant presented and published the results of this work at the First NASA URC Technical Conference in Greensboro, North Carolina, and at the 11th Annual Technical Conference of the American Society for Composites in Atlanta, Georgia.

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Studies in Shock-Wave Interactions with Homogeneous and Isotropic Turbulence

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INTRODUCTION

The development of future aircraft demands a better understanding of the nonlinear response of turbulent flows to interactions with shock waves, which may lead to improvements in calculation methods that involve turbulence modeling. As a part of this project, an experimental study of a compressible, subsonic, grid-generated, decaying turbulent flow has been performed using instrumentation with spatial resolution on the order of 7 to 26 Kolmogorov viscous length scales.

RESEARCH ACCOMPLISHMENTS

A variety of turbulence-generating grids provided a wide range of turbulence scales, with flow Mach numbers ranging from 0.3 to 0.6 and turbulent Reynolds numbers up to 700. The isotropy of the present flow was verified experimentally, and the anisotropy tensor was found to be within the range reported for incompressible flows. The present

work has established that isotropic compressible turbulence at moderate subsonic Mach numbers can be set up experimentally. The decay of Mach number fluctuations was found to follow a power law, similar to that describing the decay of incompressible isotropic-turbulence. It was found that the decay coefficient and the decay exponent decrease with increasing Mach numbers, while the virtual origin increases with increasing Mach numbers. A mechanism possibly responsible for these effects seems to be the inherently low growth rate of compressible shear layers emanating from the cylindrical rods of the grid. Taylor's microscale seems also to increase with increasing Mach numbers. Additionally, Kolmogorov's length scale decreases as the Mach number of the flow increases. The results also indicated that this scale increases as the mesh size increases.

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Langley Research Center (Abstracts)

Phenylethynyl Containing Polyarylene Ethers/Polyimides Resin Infiltration of Composites

Principal Investigator: Dr. DeRome O. Dunn
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Date of Original Award: 1996

ABSTRACT OF PROPOSED RESEARCH

New experimental thermosetting resins based on phenylethynyl containing polyarylene ethers/polyimides recently synthesized at the Langley Research Center (Dr. Brian J. Jensen, Composites & Polymers Branch) are intended for high-temperature applications. Typical high-temperature polymers inherently have elevated melt, flow, and cure temperatures along with associated higher viscosities, making fabrication difficult, but these experimental resins are being designed to moderate these behaviors.

The intent of this investigation is to experimentally evaluate their processing and mechanical performance as laminates formed from plain weave carbon fiber preform. This research will be performed within the facilities of the Center for Composite Materials Research (CCMR) at North Carolina A&T State University. The CCMR is experienced in polymeric-based composite fabrication and is associated with other organizations that enhance the performance of this proposal. Also, the CCMR has the facilities to conduct the mechanical evaluations of the created composite laminates.

A visit to NASA Langley Research Center identified personnel within the Composite & Polymers Branch that compliment this research. We plan to travel to Langley during summers to train the Principal Investigator and students. Opportunities for Langley personnel to visit the CCMR for seminars and a review of facilities are planned.

The research will begin with the development of 1 by 3 by 0.1 inch samples from as many as five candidate variations of the resin for screening during the first year. During the second and third years, a single resin system will be identified and laminate size scaled up to produce evaluation 12 by 12 inch panels. Film infusion is chosen as the first primary infiltration method to begin the studies; however, other infiltration methods may be found more suitable and applied based on the available form of the matrix and the quality of the laminate produced. Finally, studies will start after the first year using other high-temperature resin systems and processing methods, such as resin transfer molding, for comparison with the new experimental resin's film infusion results.

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Micromechanical Characterization and Texture Analysis of Direct Cast Titanium Alloy Strips

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Date of Original Award: 1996

ABSTRACT OF PROPOSED RESEARCH

The objective of this proposal is to investigate the proceeding-structure-property relationship in direct casting of titanium strips, using a newly developed technique funded by NASA Langley, "Melt Overflow Rapid Solidification Technology." It is our intention to investigate fatigue life, texture formation, and superplastic properties of material produced by this technique and the subsequent cold rolling process resulting in higher performance foils. We propose to improve the microstructure and mechanical property of the cast titanium alloys by developing a set of cold-rolling, hot pack-rolling, superplastic-forming processes and measuring the mechanical property of these materials during each step of the processes.

Three different titanium-based alloys, Ti6AL4V, Ti6242, and Ti6222, as well as an orthorhombic titanium aluminide, Ti22A1-23Nb, will be processed by the investigators using a facility owned by NASA's Langley Research Center, while the microcharacterization and secondary processing (cold-rolling, etc.) will take place at the FAMU-FSU College of Engineering.

The initial work will consist of texture analysis of in-stock titanium strips and cold-rolled foils produced earlier by NASA. Two techniques of texture analysis, x-ray diffraction and electron-backscattered Kikuchi diffraction, will be used in this work. This will be followed by microstructural characterization of the materials using both optical and electron microscopy. Data obtained from all these analyses will then be correlated with the mechanical data (fatigue, life, stiffness, strength, and mechanical anistropy). This will provide insight to the production of the final foil material with improved properties.

The second stage of the process includes theoretical and experimental investigation of the effects of processing on improving the mechanical properties. Finally, the results will be analyzed, and new materials with improved mechanical properties will be produced and characterized.

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Active Control of Aerodynamic Noise Sources

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Date of Original Award: 1996

ABSTRACT OF PROPOSED RESEARCH

The scope of the proposed research is to address issues of aerodynamic noise reduction by active flow-field control. This research will interface closely with NASA's Advanced Subsonic Technology program—in particular with the Focused Program on Noise Reduction. As these NASA programs combine a range of unique capabilities in a complementary fashion to address aerodynamic and aeroacoustic issues, this program will enable the near-term development of active control technologies through a series of small-scale experiments. These experiments, to be conducted in New Mexico State University's Low Turbulence Water Channel Facility, will provide unique capabilities for flow-field diagnostics, which are often prohibitive in larger scale facilities.

We will rely on current NASA-industry efforts to identify key noise sources and to define acoustic behavior. Our effort, at least initially, will focus on the flow field near the end of a deflected trailing-edge flap. Through this research, we will define the flow-field structures associated with noise generation and correlate unsteady behavior with acoustic data. We will identify sensitivities of these flow-field structures, and evaluate various means of flow-field manipulation to control behavior associated with noise generation.

Our final objective is to apply these findings into an integraded fluid-dynamic control that which effectively and efficiently reduces noise. In the process, we will also provide valuable flow-field diagnostics to support ongoing efforts to NASA and universities to measure and model these same phenomena.

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Identification of Surface and Near Surface Defects and Damage Evaluation

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Date of Original Award: 1996

ABSTRACT OF PROPOSED RESEARCH

Modern-day knowledge of materials degradation and flaw initiation dynamics is very limited. The fatigue life and component durability in aggressive dynamical and tribological environments is affected by the changes in material properties caused by degradation. Performance, reliability, maintainability, and life-cycle cost of advanced materials depend mainly on accurate predictions and an understanding of the severity of flaws caused by fatigue, impact damage, corrosion, friction, residual stresses, and other factors.

The proposed research is to develop and demonstrate a novel, automated non-destructive evaluation technique, called laser speckle shearing interferometry (shearography), capable of determining flaws and initial development of microcracking and its subsequent propagation in aluminum-, titanium-, and nickel-based superalloys and composite materials. This includes the characterization and space-time evolution of material properties in an aggressive dynamical and tribological environment (fatigue, flaw initiation and propagation, friction, etc.).

The four significant factors in final failure—namely, the number and character of the flaws, the load environment, the residual stress level, and the mechanism of failure for the material—will be investigated. The technique will be enhanced with other techniques, such as dual beam digital Shearography and the phase shift method. The results obtained from this approach will be compared to and coupled with results from other techniques such as Moire interferometry and laser speckle photography. This will help in establishing a better understanding of the behavior of the materials under such conditions.

By allowing fundamental real-time measurements to be made in situ, the fast detection of defects, such as disbonds and microcracking, can be achieved. In addition, the development of engineering models can be attained and thus will contribute to improved basic studies of superalloys and composite materials under various operational conditions. The current technique possesses several advantages with respect to simplicity, accessibility, and versatility. Moreover, the technique is viable and suitable for operation in a manufacturing environment or department/repair facility and in the field.

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Lewis Research Center (Reports)

Novel Flow Configuration for the Study of Turbulent Flame Propagation

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Date of Original Award: 1993

INTRODUCTION

Premixed flame propagation in turbulent flow is being investigated experimentally using a Taylor-Couette flow reactor. A fully developed turbulent flow is generated in the annulus between two concentric cylinders rotating in opposite directions. A flame is ignited at the open top end of the apparatus and propagates downward through the annulus. The propagation rate of the flame and its dependence on turbulence intensity is measured and compared with earlier experimental results. A TSI laser Doppler velocimetry system is used to measure turbulence intensities, while a video camera is used to record the advancement of the flame downward through the apparatus.

RESEARCH ACCOMPLISHMENTS

Since the last reporting period, flame speeds in turbulent methane-air mixtures have been measured for turbulence intensities up to 120 cm/s, and good agreement with measurements made by earlier investigators has been

obtained. The intensity of 120 cm/s is 12 times the rate with which a laminar flame (unwrinkled by turbulence) would propagate through a nonturbulent mixture of the same reactants, and it is high enough to attain the small-scale combustion regime where the internal structure of the flame is modified by the turbulence.

BENEFITS TO SOCIETY

The goal of the work is to identify the mechanism responsible for the decreasing sensitivity of the turbulent-flame speed with increasing turbulence intensities. The effect of this mechanism makes it unfeasible to achieve higher power output from combustion devices, such as automobile engines and gas turbines, by enhancing turbulence in the flow of reactants. A benefit to society of the identification and understanding of this mechanism is better control of combustion power output and emissions by engine designers.

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Dielectric Spectroscopy as a Materials Probe

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Date of Original Award: 1993

INTRODUCTION

The focus of this project has been the development of a nondestructive testing technique that could be used to detect mechanical, environmental, and electrical degradation in critical components used in NASA's missions. The project emphasizes the combination of spectral and spatial measurements for the detection of cracks in structural components and the development of leakage currents in electronic components, especially in those that are ferro-electric. The techniques being used include impedance and dielectric spectroscopy and DC resistivity measurements.

RESEARCH ACCOMPLISHMENTS

During this period, the greatest emphasis was placed on the characterization of the frequency dependence of the dielectric properties of ferro-electric thin films, and substantial progress was made. Several key papers were presented at various meetings, including the Materials Research Society and the American Ceramic Society. Two refereed papers have been published, and others have been accepted. The major contribution of this work is that the microstructure of the thin film was found to play a very important role in the resultant dielectric response. In particular, epitaxial films show virtually no frequency dependence, while polycrystalline films demonstrated a large frequency dispersion. Additional relaxation effects related to coupling of the high capacitance of the ferro-electric with the inductance of the leads and pinning of the domain wall motion were also detected. Enough work was generated that plans to request funding for a project focusing on the ferro-electric materials will be made shortly.

We also continued our exploration of the effects of porosity (and thus cracks and voids) on the dielectric response, and one paper was published and two were presented at an IEEE conference. An invited talk was given at a university, and numerous requests from other leading universities for information on this subject have been made. Approval to write a feature paper on the dielectric properties of porous materials for the *Journal of the American Ceramic Society* has been granted. In this paper, the effect of the size, shape, and volume fraction of voids on the resultant dielectric response will be discussed. In addition, signature responses of porous materials associated with moisture picked up from the atmosphere or entrapped in the structure will be clearly distinguished.

Another important outcome of this project was the principal editorship of a proceedings book by the Materials Research Society (435 pages), *Electrically Based Microstructural Characterization* (ISBN-1-55899-314-2), for which NASA received an acknowledgment in the preface. This book describes many different applications for the techniques and materials used in this project and will serve as an excellent reference.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

Ferro-electric materials are at the heart of many recent solid-state developments, and they play an important role in the sensors and actuators operated by NASA. Further, the results of the work on the effects of porosity are believed to be relevant to NASA, as a major contractor to NASA's Lewis Research Center has recently negotiated a contract for a related investigation at another university. Because this project will be ending shortly, help in contacting the interested parties will be greatly appreciated.

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Distributed Bragg Region Sensors with Aerospace Applications

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Date of Original Award: 1994

INTRODUCTION

The research conducted under this grant involves the study of ultraviolet (UV)-induced photorefractive effects in optical fibers, with an emphasis on the use of the resulting Bragg reflection filters for generalized distributed sensing and, in particular, nonintrusive aerodynamic flow mapping. In addition, studies involving interferometric fiber devices with applications to miniaturized fiber sensor readouts are a primary focus, as they relate to distributed sensor interrogation. The general objective of the funded research effort is the development of distributed sensors and fiber-optic centered opto-electronic networks for the intelligent monitoring of phenomena in various structures. Specifically, our aim is to fabricate a distributed sensor system using D-type fibers, which can be incorporated into the surface of a structure to sense pressure field variations.

RESEARCH ACCOMPLISHMENTS

We have completed the building of a prototype for multiple sensor fabrication as shown in the schematic of Figure 1a. This prototype consists of a high-resolution, automated writing system, which contains a double interferometer setup (one visible, as shown in the photograph of Figure 1b, and the other UV).

We have verified the interference fringe spacing in D-type fibers using the photographic technique of grating-fiber image reproduction. This has led to the design of a new tunable writing device, as well as to a deeper understanding of the physics surrounding phase mask design and fabrication (see Figure 2a).

We currently have fabricated several V-grooved fixtures for use in aerodynamic sheer-stress measurements. D-fibers with Bragg gratings have been placed into the

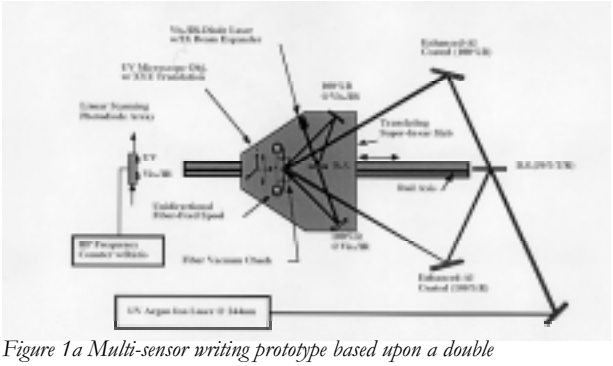

Figure 1a Multi-sensor writing prototype based upon a double interferometer wavelength comparator.

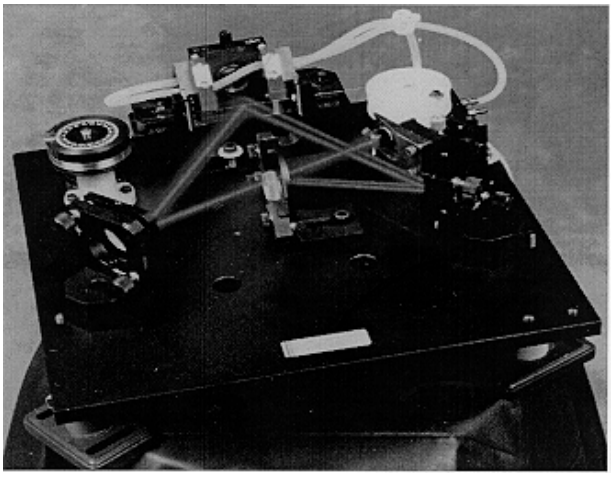

Figure 1b Bragg reflection filter wavelength comparator or standard.

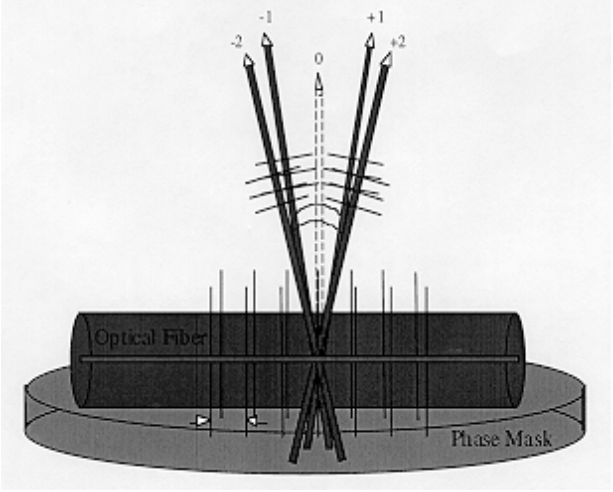

Figure 2a 1st and 2nd order diffracted beams generated by a phase mask.

grooved regions and covered with a thin layer of epoxy, so as to appear to be a part of the normal, smooth surface of the fixtures. In addition, we have set up, using compressed air with regulators, a fixture for controlled but variable flows across the surfaces of these same sensor-embedded units. Data from these more advanced experiments is forthcoming.

We have obtained preliminary evidence that these sensors may have reasonable responses and are therefore setting up more elaborate measures to quantify and possibly enhance their sensitivities. We also have a few simple designs for optimizing the response of the sensors for their present configurations. Figures 5 and 6 relate to sensor enhancement by using matched Bragg filters. Sensitivity enhancements also include the choice of materials in which the sensors are embedded, as well as a possible amplification of the strain transfer to the D-fiber sensors using gradations of materials.

We have set up a preliminary Bragg grating calibration cantilever beam, where we have placed a parallel commercial strain gauge. We are able to see both the wavelength shift caused by straining the Bragg units and the commercial strain gauges. This allows us to generate strain vs. wavelength calibration curves for the fiber grating sensors.

At present, we have developed a miniature fiber optics spectrum analyzer for readout verification and characterization of distributed Bragg filters within a given fiber unit. This verification method involves the device shown in Figure 3a. Its preliminary response to a single frequency, actively stabilized He-Ne laser is shown in Figure 3b. We currently are using the illumination of a reflection filter with a superluminescent laser diode light source and detection of the back-reflected signals at the Bragg wavelengths. These signals can be further characterized in linewidth and reflection amplitude, using a commercial spectrum analyzer (HP 70004A and HP 71451A). In addition, a tunable laser with wavelength scanning capabilities is being used. In our case, we use a Ti:Sapphire laser set up to scan from 780 to 870 nm.

Our findings, noted in a recently reworked paper titled "Experimental and Theoretical Investigations of Phase Mask Defects Using Bragg Reflection Gratings" (H. Lee, Z. Ndlela, J.V. Lindesay, and D.R. Lyons), have led to a patent disclosure and to the development of a new class of tunable diffractive devices. In addition, we have received a patent for a device that is projected to greatly impact our ability to create high-definition distributed sensing systems, titled "Method of and Apparatus for Calibrating Precisely Spaced Multiple Transverse Holographic Gratings in Optical Fibers" (D.R. Lyons and

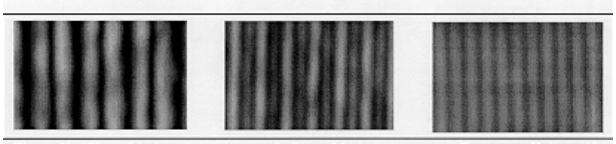

Figure 2b. Phase Mask Period = 1.059mm | Phase Mask Period = 0.566mm | Transverse Holographic q = 25 degrees

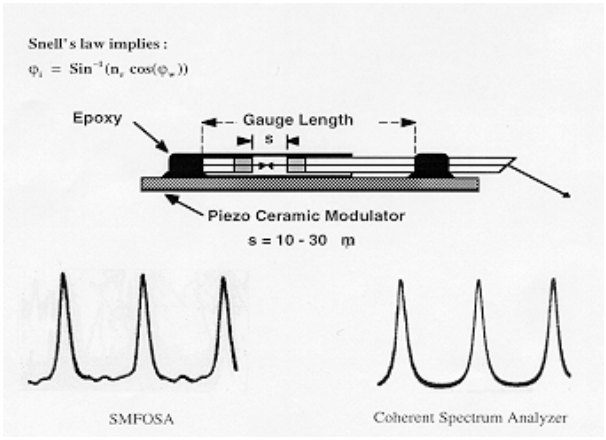

Figure 3a Single mode fiber optic spectrum analyzer for use as a compact Bragg grating readout.

Zolili Ndlela). We were notified of this issuance in the Spring of 1996.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

The primary goals and current accomplishments of this research demonstrate how fiber-optic sensors can be fabricated for incorporation into aerospace structures or aerospace environments for monitoring parameters such as temperature and pressure, as well as for feedback control.

Such feedback information and control is needed to ensure the manufacture of materials that will be optimized to satisfy the long-term structural requirements critical to aerospace efforts and to minimize waste and materials costs. High-quality and low-cost advanced composites and other materials will also allow uses in a wider range of aerospace structures and dual-use applications. In addition, the eventual realization of an array of such sensors deployed in various structural components and various remote or inaccessible environments may perform health or environmental monitoring functions in real time.

BENEFITS TO SOCIETY

The work being done here continues to have profound implications for advances in aerospace (aerostructures intelligent enough to do self-monitoring and save millions of lives), telecommunications (high volume active and passive switches and splitters for wavelength division mul-

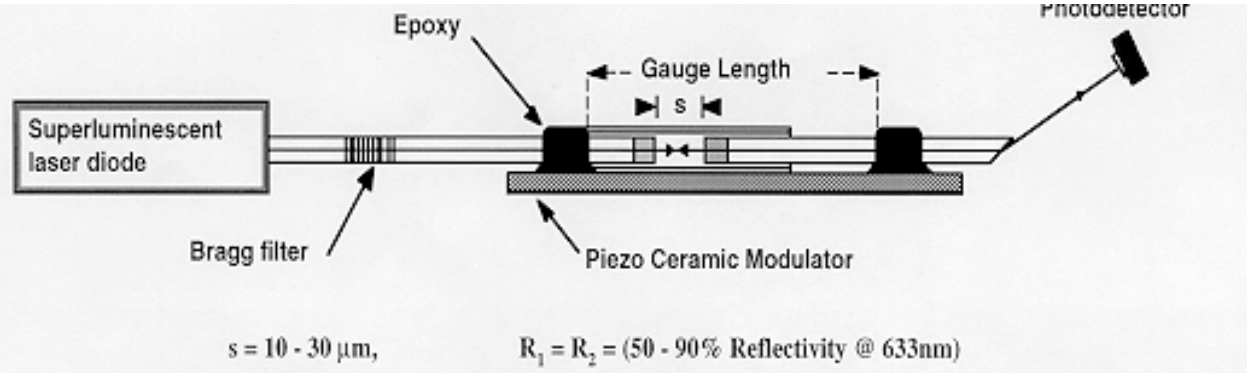

Figure 3b Bragg grating detection using in-house constructed SMFOSA.

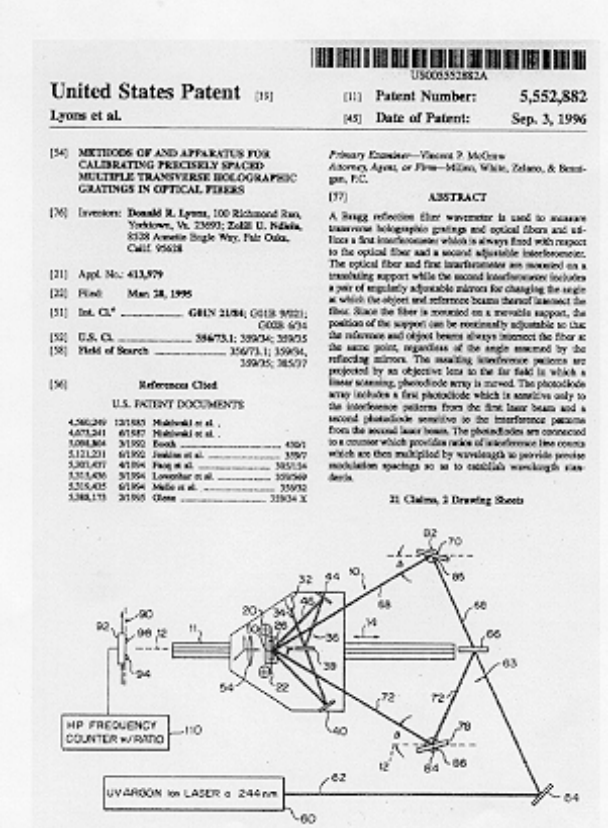

Figure 4 High volume Bragg grating wavelength comparator. Note: Notification of issuance was given in May 1996.

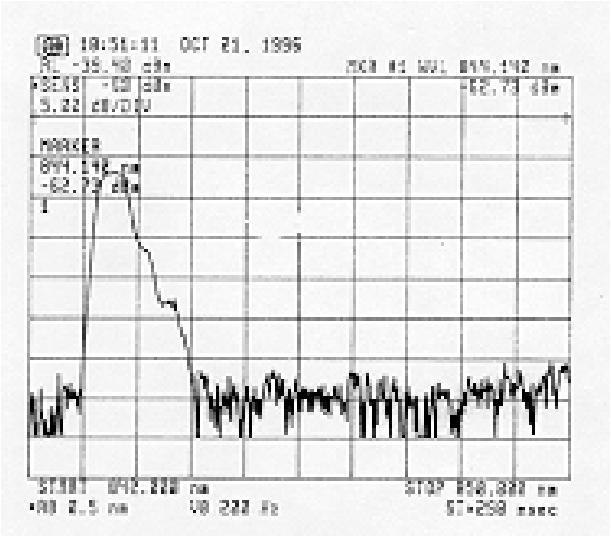

Figure 5 Identical unperturbed Brag gratings for resonance enhanc.

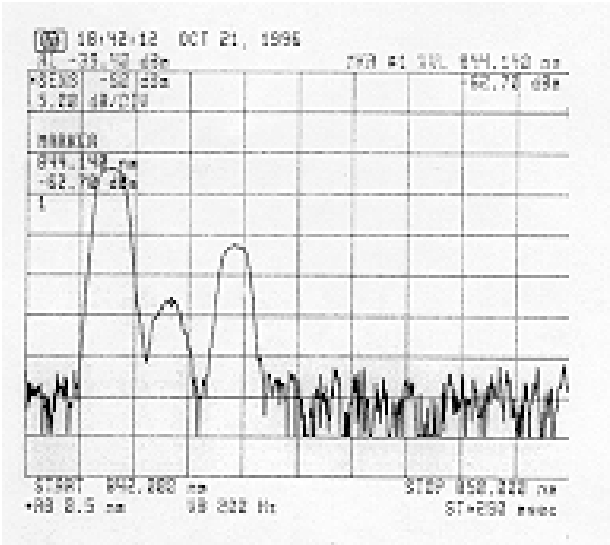

Figure 6 Identical perturbed Bragg gratings for resonance enhancement.

tiplexing), medicine (artificial nerves at density levels approaching that of the human nervous system), and other fields.

STUDENT ACHIEVEMENTS
At the present time, there are two graduate and two undergraduate students involved in these experiments. One student, Kenneth Samuel, has given several talks and technology demonstrations and has received additional grants for graduate study. His accomplishments include: "Strain-Optic Effect for UV-Induced Bragg Gratings," NASA-URC Conference, North Carolina A&T (Spring 1996) and "Fiber Optic Bragg Grating Strain Sensor Research," Virginia Space Grant Consortium Fellowship Award, 1995–96.

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Nonlinear Dynamic Analysis of Mistuned Bladed-Disk Assemblies

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Report not submitted.

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Turbulent Premixed Methane-Air Combustion: Emissions, Characteristics and Modeling

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Date of Original Award: 1995

INTRODUCTION
This study is aimed at enhancing the understanding of turbulent premixed methane-air combustion. The specific objectives of the study are to establish the effects of process variables (such as flow rate, fuel/air ratio, and the presence of chlorinated hydrocarbons) on the emissions and flow structure (velocity distribution, streamlines, vorticity, and flame shape) and to develop a mechanistic model to explain the observed trends.

RESEARCH ACCOMPLISHMENTS
The specific tasks accomplished in the first year of the project included: the completion of the literature review, the acquisition of all necessary equipment and supplies, and the design, construction, and testing of the experimental facilities. The experimental setup, including all analytical and diagnostic instruments, was completed and tested. Preliminary data on the effects of flow rate, fuel/air ratio, and the presence of chlorinated hydrocarbons on the emissions and flow structure were obtained. It is, however, too early to present the results. Therefore, details of the results will be presented and discussed in the next report.

In addition to the experimental program, the development of a numerical model to explain and predict the results was initiated. Two numerical codes have been installed and are currently being evaluated. The code with the most potential will be further modified and used to explain and enhance the understanding of the fundamental mechanisms involved in the process.

RELEVANCE TO NASA STRATEGIC ENTERPRISES
The success of the program will provide the experience and experimental baseline (normal gravity) data for a future microgravity study of the methane-air combustion system, either in a droptower or in flight. It will also en-

hance the fundamental understanding of turbulent premixed methane-air combustion.

BENEFITS TO SOCIETY
The understanding of turbulent premixed combustion of methane or natural gas is essential because the characteristic dimensions and flow rates of most industrial equipment are often large enough for flows to be turbulent. Many industries are pursuing lighter hydrocarbon alternative fuels, and the use of a premixed flame reduces pollutant emissions.

STUDENT ACHIEVEMENTS
LaShanda James, a chemical engineering student working on the project, was one of a few outstanding junior students selected nationwide to participate in the 7th Annual Opportunities in Engineering Conference at the University of Wisconsin at Madison.

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Lewis Research Center (Abstracts)

Development of Synchromously Scanned Optical Parametric Oscillator (OPO) Coherent Antistokes Raman Spectroscopy (CARS) as a New Probe for Hostile Environments

Principal Investigator: Dr. Peter C. Chen
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Date of Original Award: 1996

ABSTRACT OF PROPOSED RESEARCH
Hostile environments, such as those with high temperatures and pressures, highly reactive species, and high levels of background light, are not uncommon to the technologies needed to improve our capability for space exploration. Such technologies include combustion, propulsion, plasmas, and chemical vapor deposition. Studies on such systems would greatly benefit from a noninvasive, in-situ probe that would provide temporal and spatial information in a flexible and universal way. For example, a laser probe technique that could identify and distinguish all molecular species at a given point in time and space could be used to study aromatic/hydrocarbon species involved in new propulsion systems to optimize the efficiency and reduce the production of harmful byproducts.

The purpose of the proposed research is to complete Phase I of a two-part project: to study, develop, and prepare a new laser probe technique, called Synchronously Scanned OPO CARS, that would have unique capabilities well-suited for analysis in hostile environments of interest to NASA. The proposed work will significantly improve conventional CARS, a technique already well known as a tool for analysis in hostile environments. First of all, by replacing the dye laser with an OPO, the scan range for CARS will increase by almost two orders of magnitude. Instead of being used to probe only a handful of species, this new technique will be capable of conducting a complete qualitative and quantitative analysis. Second, the use of synchronous scanning should result in greater stray light rejection, improving the ability to detect species at trace concentration levels. Finally, simultaneous monitoring of atomic and molecular species could be achieved. The result will be a powerful new tool for performing noninvasive, in-situ, spatially resolved qualitative and quantitative analysis in hostile environments. A future proposal for Phase II will involve applications of this new technique in NASA-related projects.

The proposed effort will also provide valuable research training for undergraduate students from groups that are underrepresented in science, engineering, and mathematics. Spelman College is one of the Nation's two HBCU's for women and has an impressive record of preparing students for graduate work in science, engineering, and math areas. As research assistants in the college's new laser laboratory, the students will have major responsibilities in conducting the proposed research and presenting the work at regional and national meetings.

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Cubic Boron Nitride Alphavoltaic Devices

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Date of Original Award: 1996

ABSTRACT OF PROPOSED RESEARCH

A promising technology for space power applications is alphavoltaic energy conversion, a concept related to photovoltaics. The essential process consists of bombarding a semiconductor pn junction with high-energy alpha particles, with the intent of converting some fraction of the particle energy to electrical energy.

The major technological hurdle for alphavoltaic technology is that the alpha particles tend to degrade the device performance, limiting the power system lifetime. The concept has been demonstrated using silicon-based devices, but to make the technology economically feasible, an alternative semiconductor material with good radiation resistance is required. A strong possibility for such a material is cubic boron nitride, which has a bandgap energy of approximately 6 electron volts and is therefore likely to demonstrate the necessary degree of radiation resistance.

The proposed project will concentrate on the growth and characterization of cubic boron nitride using pulsed laser deposition techniques. Doping experiments will be conducted to fabricate initial test devices, which will be evaluated in an alpha particle environment to determine the potential for power conversion.

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Polymerizable Monomer Reactants-Modified Polyimides

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Year of Original Award: 1996

ABSTRACT OF PROPOSED RESEARCH

The main focus of this research investigation is to prepare diamine derivatives of Bis-(p-nitrophenoxy)-1,1'-biphenyl, Bis-(2,2'-p-nitrophenoxy)- 1,1'-binaphthyl, 2,7-dinitroflourene, and other "ether" diamines of a bulky, chemical structure. These materials will be used to modify polyimides as end-capped moeities as part of our efforts to form materials made of graphite fiber/in-situ polymerizable monomer reactants (PMRs).

PMRs are major components in state-of-the-art technology for the aeropropulsion industry. Through molecular design, we will introduce the types of molecular functional groups that cause a lowering of the melt-processing temperature required to (melt) process high-temperature polyimides, such as, PMRs. As part of the main focus, we hope to develop new polyimides that can be processed by cost-effective techniques, such as resin transfer molding.

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Growth and Characterization of III-V Semiconductors for Device Applications

Principal Investigator: Dr. Michael D. Williams
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Date of Original Award: 1996

ABSTRACT OF PROPOSED RESEARCH

The research goal is to achieve a fundamental understanding of the physical processes occurring at the surfaces and interfaces of epitaxially grown InGaAs/GaAs (100) heterostructures. This will facilitate the development of quantum well devices for infrared optical applications and provide quantitative descriptions of key phenomena that impact their performance.

Devices of interest include high-speed laser diodes and modulators for fiber-optic communications at 1.55 μm wavelengths and intersub-band lasers for longer infrared wavelengths. Phenomena of interest are strain effects on the electronic structure of the material and the migration of indium in InGaAs quantum well structures.

The program is centered on the molecular beam epitaxy reactor and characterization apparatus donated to Clark Atlanta University by AT&T Bell Laboratories. The material characterization tools that will be employed are secondary ion mass spectrometry and photoemission spectroscopy.

The training of graduate and undergraduate students is an integral part of this program. The graduate students will receive a thorough exposure to state-of-the-art techniques and equipment for semiconductor materials analysis as part of the master's-degree requirement in physics. The undergraduates will be exposed to a minority scientist who has an excellent track record in this area. They will also have the opportunity to explore surface physics as a career option. The results of the scientific work will be disseminated in refereed journals and through talks at professional conferences.

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Marshall Space Flight Center (Reports)

A Computer-Based Tool for Evaluating Graphical User Interfaces

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Date of Original Award: 1993

INTRODUCTION

There were two objectives for this year. The first was to extend the first year's work to include a training component. During the first year, a Graphical User Interface Evaluation Tool (GUIET) was designed to assist designers in the process of formative evaluation. GUIET evaluates the user's mental model of the system against the designer's conceptual model. This approach was extended to provide the user training on the designer's conceptual model. The second objective was to develop an expert system to assist in the design and evaluation of user interfaces based on rules and guidelines.

RESEARCH ACCOMPLISHMENTS

A Generic (Rule Based) Training System (GETS) was developed to provide the user information on the designer's conceptual model of a system. It uses an expert system tool to control the execution of rules that describe the application. GETS is composed of three modules: the application module, the training system module, and the User Action Notation (UAN)-Rule translator module. The application module is the external system on which the user will be trained. The UAN-Rule translator module converts a description of all tasks that can be performed using the application system to a rule base for the expert system. The training system module is in charge of monitoring the steps the user is performing on the application system and offering assistance where needed.

The Expert Advice System for Graphical User Interface Design and Evaluation was also developed. This is a motif-based graphical user interface (GUI) that contains a database, an expert system, and an evaluation tool. General information on the design and evaluation of GUIs is stored in the database. The user might also request design advice (such as the best background color or the most appropriate foreground color to be used with a particular background). The design advice is stored within the expert system.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

The capability to objectively evaluate GUIs would significantly enhance the quality and functionality of the interfaces, while at the same time reduce development costs. The research that has been completed provides a suite of computer-based tools for objectively evaluating GUIs, which will be valuable in supporting and evaluating program and project user interface development. Most of our collaboration has been with the Mission Operation Laboratory's efforts in developing onboard, graphical payload displays for the Space Station; however, this tool could also prove valuable to other projects, such as the Hubble control center. We have demonstrated the system at Marshall Space Flight Center and have subsequently installed the prototype on their system.

BENEFITS TO SOCIETY

Computers are now being used in every aspect of life; however, much research is needed to determine ways to make computers easier to use. The research that we are conducting seeks to improve the usability and understandability of all computer interface designs.

STUDENT ACHIEVEMENTS

Three master's theses have been completed and presented during the contract period. A refereed paper has been

accepted, and another is currently being reviewed. One undergraduate who completed her B.S. during this period is now working at the Eastman Kodak Company. A graduate student funded through the program is working at Texas Instruments, and another graduate student is continuing in our Ph.D. program.

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Marshall Space Flight Center (Abstracts)

Atomization in Impinging-Jet Injectors of Liquid-Propellant Rocket Engines

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Date of Original Award: 1996

ABSTRACT OF PROPOSED RESEARCH
First, the problem of predicting the spray characteristics of the impinging-jet atomizer, such as that used in liquid-propellant rocket engines, will be considered. Then, an innovative mathematical formulation that takes into account the effect of fuel and oxidant properties will be advanced.

The present formulation makes use of physical observations to simplify an otherwise complex system of equations that govern the instability phenomenon that leads to the atomization process in the impinging-jet atomizer. It is proposed that a numerical solution to the problem may be obtained by the finite-difference technique. A computer code that will accept normally known parameters (such as, jet properties, velocity, and diameter) as input and compute the outcome of the atomization process, such as the resultant fuel-drop size and orientation, will be developed.

Such results are needed as prerequisite parameters in currently used sophisticated combustion simulation codes that, at present, make use of ad hoc assumptions regarding these parameters. Extensive validations of the predictions of the proposed theory against existing experimental data and empirical correlations are planned. The results of the proposed effort are expected to enhance the ability to perform a controlled design of the combustion processes that take place in liquid-propellant rocket engines.

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3-D Multiphase-Flow Modeling of Oxygen Flow Systems

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ABSTRACT OF PROPOSED RESEARCH
Safety assessment and analysis of oxygen flow systems are very important. Systems of interest to NASA include the Shuttle main engines, life support systems both onboard and in spacesuits, and spacesuit emergency thrusters that are under current consideration. Pure oxygen is by nature a hazard whenever a combustion potential exists. Two possible sources for ignition are very rapid gas compression and high-velocity particle impact, both transient phenomena. It is the latter problem that is addressed in this proposal.

The White Sands Test Facility (WSTF) of the Johnson Space Center is engaged in an experimental program to assess the hazards associated with supersonic velocity particle impact (SVPI) in oxygen systems. An SVPI chamber is used to study the effects of flow velocity, pressure, temperature, and particle material on ignition. This valuable work has been very useful, but largely empirical, to date.

It is proposed that a commercial flow code, CFDS-FLOW3D, be used to model the SVPI chamber. This modeling will address the three-dimensional, transient, compressible, and multiphase aspects of the flow. The model will be verified against pressure and temperature data that will be generated experimentally by WSTF personnel. An accurate model of the SVPI chamber will not

only answer questions about particle velocity at impact, but will be a valuable tool in determining the direction of future experiments, as well as the possible redesign of the apparatus to better simulate real hardware issues.

At the conclusion of the project, a flow model will be available to NASA that will address the full conjugate heat transfer problem. In addition, an ignition model will be developed to predict those conditions that lead to combustion on impact. It is anticipated that the successful development of this model will provide a design tool for flow systems well beyond that of the SVPI chamber.

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Object-Oriented Software Control Architecture for Robotic Vehicles

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Date of Original Award: 1996

ABSTRACT OF PROPOSED RESEARCH
This project investigates the use of object-oriented (OO) technology to develop the Strategic-Tactical-Execution Software Control Architecture (STESCA) for use in robotic vehicles. In conjunction with the Naval Postgraduate School (Monterey, California), we have previously developed the Rational Behavior Model (RBM).

RBM is a three-level software control architecture for robotic vehicles, and it has been successfully used in controlling an autonomous underwater vehicle (AUV). RBM's top Strategic level utilizes logic programming languages for mission specification. The middle Tactical level models the vehicle using OO concepts, serving as a bridge between the top and bottom levels. The bottom Execution level uses conventional C code to control motors, control surfaces, and sensors.

One problem with the current implementation of RBM is that the top Strategic level and the middle Tactical level do not communicate very well. As a result, much of the logic that should be implemented in the Strategic level has been pushed down into the Tactical level, which has limited the success of utilizing a three-level approach and OO technology.

This project will be divided into three main phases. The first phase will be to relax some of the restrictions of RBM in creating the more general STESCA for the AUV utilizing both OO technology and a three-level approach. The second phase will be to implement STESCA, using OO technology, for the simulator into the actual vehicle. The third phase will validate STESCA as a more general alternative to RBM, specifically showing that an OO approach to mission specification is viable. The second and third phases together will validate STESCA as a software control architecture and show that OO technology can be used to enhance the development of robotic vehicles in general.

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Development and Testing of a Vibrometry Technique for Health Monitoring of Composite Material Structures

Principal Investigator: Dr. Mark J. Schulz
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Date of Original Award: 1996

Advanced aircraft and space vehicles use lightweight composite materials that are more susceptible to damage than metals. To ensure safety and serviceability of these systems, it is necessary to monitor the structural integrity continuously and to detect and locate often invisible damage and faults when they occur, before becoming catastrophic.

The proposed research is to develop an accurate and efficient health monitoring technique to detect damage to composite substructures on high-speed aircraft, satellites, and space vehicles. The nondestructive evaluation (NDE) technique will enhance the reliability and safety and reduce the cost of maintenance of NASA equipment.

Present techniques for NDE of composite materials include conventional methods such as ultrasonic scanning,

radiographic inspection, visual inspection, dye penetrant, acoustic emissions, smart paints, and new methods (such as embedding fiber-optic wires and vibration signature analysis). Conventional methods are accurate, but time-consuming and expensive, whereas embedding wires is difficult on a large scale. On the other hand, vibrometry techniques are a global type of NDE and have the potential to detect damage far away from a sensor location, but are in their infancy of development.

In this proposal, a new Transmittance Function Monitoring (TFM) technique will be used to detect and locate delaminations, impact damage, moisture absorption, and voids in laminated and resin transfer molded composite structures. Innovations of this approach are that no structural model is needed, input vibration does not need to be measured, and damage can be detected on-line using random ambient excitation and the nonresonant part and zeros of the Transmittance Function. The TFM technique will be developed through computer simulation and extensive experimentation. Undergraduate through Ph.D.-level minority and economically disadvantaged students will participate in this project.

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Stennis Space Center (Reports)

Optimal Rate Concept Acquisition for Classification of Remotely Sensed Spatial Data and Propulsion Test Data

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Date of Original Award: 1994

INTRODUCTION
Image processing is the manipulation and interpretation of digital images using a computer. One of the image-processing tasks involves classification, the process of assigning the pixels of an image (that is, the most elemental component of the image, sometimes called a raster) to one of several land-cover classes or thematic categories. This technique provides a quantitative method for automating the identification of features in a scene. The main objective of this research is to investigate and demonstrate the use of artificial intelligence expert systems technology for the classification task. The overall research effort includes surveys and evaluations of expert systems shells, surveys and evaluations of knowledge discovery techniques for uncovering relationships in raw data, and the implementation of prototype classification systems.

RESEARCH ACCOMPLISHMENTS
A machine-learning technique, which combines the version space method for concept acquisition and the genetic algorithm technique for optimization, has been implemented. This technique, called Optimal Rate Concept Acquisition, not only produces descriptions of classes, but also suggests the best examples of raw data to use for training the classification system. Testing has shown the accuracy rate for the version space classifier to be comparable to other classification systems (such as, neural network systems). However, the version space systems can be trained using far less data than other classifiers, and they produce descriptions of the data that can be easily understood by humans.

RELEVANCE TO NASA STRATEGIC ENTERPRISES
NASA now has, and will continue to collect, vast amounts of remotely sensed spatial data. However, much of these digital data are unidentified and therefore unusable in their present form. This project addresses a technical problem that is vital to NASA's Mission to Planet Earth: analyzing, classifying, and extracting useful and usable information from the vast amounts of data that will be generated by the Earth Observing System (EOS).

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Land Use Patterns and Fecal Contamination in Coastal Waters of Western Puerto Rico

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Date of Original Award: 1993

INTRODUCTION

This project is investigating how land-use patterns affect the microbiological quality of rivers flowing into Mayagüez Bay in western Puerto Rico. Satellite and airborne imagery have been used to study watershed land-uses that serve as nonpoint sources of pathogens affecting stream and coastal water users. Land use and land cover in the study watersheds are being interpreted and mapped using remotely sensed images from NASA's Thematic Mapper (TM) and Calibrated Airborne Multispectral Scanner (CAMS). Classification was made combining TM bands 4, 3, 2, and the reflection patterns on infrared, green, and blue bands in aerial photographs. The Guanajibo, Añasco, and Yagüez watersheds were classified to compare forested areas, pastures, agricultural zones, and urban areas, so as to determine their contribution to fecal water contamination.

Figure 1 LANDSAT TM image of Guanajibo River

RESEARCH ACCOMPLISHMENTS

This study determined that significant statistical differences in microbiological water quality exist between streams and coastal areas draining watersheds with different land-use patterns. However, no significant statistical correlation was found between stream flow and density of the different microbiological water quality indicators used. This is probably because of raw wastewater discharges coming from sanitary sewer bypasses into study streams during frequent pumping station failures. The effect of nonpoint source contamination on stream water quality cannot be observed under these circumstances. These results should be of use to regulatory and health agencies dealing with water pollution control.

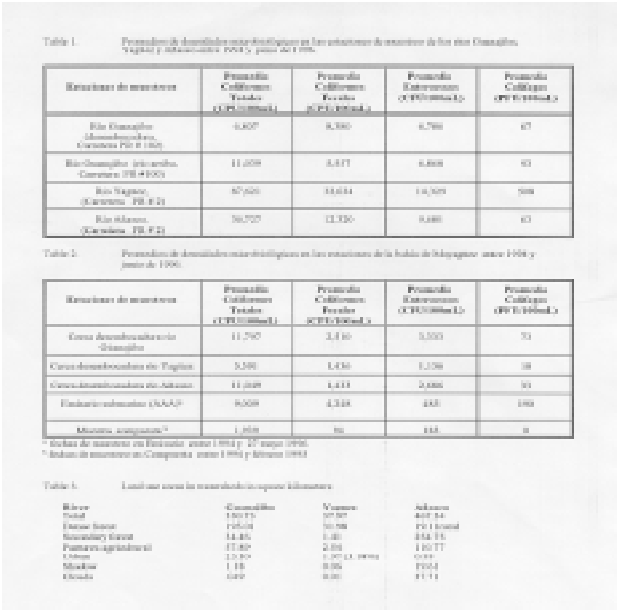
Figure 2 Tables 1 and 2 present average results of microbiological water quality analysis for the stream and ocean stations, respectively. Significant differences appear in pathogen indicator densities between the study sampling stations. A photogrametric analysis of images indicates predominant watershed land covers shown in Table 3

The quantification of land-cover areas was carried out using image analysis software (IDRISI and ERDAS packages). Figure 1 presents a LANDSAT TM image of the study area where the Guanajibo river's watershed has been delimited.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

This project involves applied research in Earth systems science. This is relevant to NASA's Mission to Planet Earth.

BENEFITS TO SOCIETY

This research project is directly related to the continuing effort to develop and employ geographic information systems and remote sensing in research, and it enhances the government's capability to analyze and develop solutions to meet the needs of the population.

STUDENT ACHIEVEMENTS

The Medical Sciences Campus conducts research continuously in basic and applied sciences related to human

health. The project has increased the amount of student participants in NASA-related fields, improving their skills in scientific and environmental research.

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A Study of the Fluid Mechanics of Reacting Flows in Selected Aerospace Propulsion Devices

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Optimization of Polymer-Dispersed Liquid Crystals (PDLCs) and Polymerization-Induced Phase Separation

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Date of Original Award: 1993

INTRODUCTION

The main thrust of this project is to optimize Polymer-dispersed liquid crystals (PDLCs) for low-speed optical interconnections, to evaluate them in nondestructive testing applications. As this project and the general knowledge of liquid crystal and polymer dispersions evolved, it became evident that more fundamental knowledge of the phase separation processes is necessary before the optimization of PDLC materials can be accomplished. Therefore, the thrust of the project was modified to investigate polymerization-induced phase separation. In addition, a microgravity study of phase separation processes was initiated in collaboration with the Microgravity Materials group at Marshall Space Flight Center. The NASA investigators at Marshall have provided three flight opportunities on the KC-135 aircraft.

RESEARCH ACCOMPLISHMENTS

The results of preliminary microgravity studies are promising and will form the basis of a microgravity materials proposal that will be submitted in March 1997. We have observed differences between terrestrial PDLCs and KC-135 microgravity PDLCs. Terrestrial PDLCs with liquid crystal weight fractions less than 50 percent have larger, more densely packed droplets than the corresponding microgravity samples. Conversely, terrestrial PDLCs with liquid crystal weight fractions greater than 50 percent have irregularly shaped and unevenly spaced droplets, whereas the corresponding microgravity samples have densely packed, uniformly spherical droplets. The electro-optical properties of the microgravity samples with weight fractions greater than 50 percent are more optimal than any other samples. This result supports the theoretical observation that a dispersion of densely packed, identical droplets will exhibit the best electro-optical properties. The knowledge gained from the microgravity research will further the effort to produce benchmark materials in the terrestrial environment, so that the utility of polymer and liquid crystal dispersions may be accurately assessed for such critical applications as high-definition flat panel displays and spatial light modulators.

RELEVANCE TO NASA STRATEGIC ENTERPRISES

Phase separation processes are vital in understanding the relationship between materials processing and the resultant microstructures. Crystal growth is an excellent example of the importance of microgravity studies. PDLCs have great potential in applications such as nondestructive testing of structural elements in the International Space Station after completion. In addition, PDLCs have other applications, including flat panel displays, architectural panels, and national defense. Further understanding of phase separation processes between liquid crystalline and polymeric materials in both terrestrial and microgravity environments will pave the path for the production of benchmark PDLC materials with applications relevant to NASA.

Ms. Kashonya Thornton succeeded in demonstrating that the relaxation times of liquid crystals confined to nuclepore membranes are well described by the traditional elastic theory, modified with a contribution associated with

the curvature of the cylindrical pore walls. This result in cylindrical pores is relevant to PDLC materials where curvature of the confining walls is more critical.

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Stennis Space Center (Abstract)

Labile and Stable Soil Organic Carbon Pools Revealed by ^{14}C and ^{13}C Signatures

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Date of Original Award: 1996

ABSTRACT OF PROPOSED RESEARCH
Soil organic carbon (SOC) is one of the major "missing carbons" in the current global carbon model because we have a poor understanding of the SOC dynamics. Recent studies indicated that SOC in temperate surface soils can at least be divided into two major categories: a labile pool with a turnover time of less than a few decades and a stable pool with a turnover time of longer than several hundred years. Differentiating those two SOC pools is critically important because they play very different roles in carbon budget and nutrient cycling.

Determination of sizes and turnover of SOC pools has been difficult. Recent developments of new approaches using ambient ^{14}C and ^{13}C signatures to study SOC dynamics seem to provide answers to the problem. I propose to study labile and stable SOC of 20 selected Mollisols and Aridisols of the Great Plains and five Oxisols and Ultisols of tropical Brazil using the ^{14}C and ^{13}C signature technique. I will explore the relationship between SOC dynamics and the factors of temperature, soil texture, management, and primary productivity. I will also identify the mean age of several aggregate-size density fractions which may represent labile and stable SOC of the selected soils. I expect this study will produce a comprehensive database on labile and stable SOC in soils of the two major geographic regions of North America. The results could be used for the calibration and validation of the current SOC and global carbon models.

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acknowledgements

The preparation of the 1996 *Research and Technology Report* was managed by Dr. Philip Sakimoto, University Program Specialist, under the overall direction of Ms. Bettie White, Director of the Minority University Research and Education Division (MURED). The Allied Technology Group, Inc., of Rockville, Maryland, under NASA contract number 5058, compiled and analyzed the data presented in this report. Allied staff members who worked on this report were Ms. Brenda Humberson, Junior Management Analyst, Mr. Sambasiva Chandu, REI Systems (subcontractor to Allied), and Dr. Alan Goodman, Consultant. Cover photograph courtesy of NASA Kennedy Space Center.

Any questions or comments concerning this document should be submitted to:

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on the cover

KENNEDY SPACE CENTER, FLA. — An early-morning launch of the Space Shuttle Discovery symbolizes the hopes and dreams of over 300 faculty-level researchers and nearly 700 students at 38 minority and 8 other institutions of higher education whose science and engineering research efforts in support of this Nation's space program have led to the reports compiled in this volume.

George E. Reese
Associate Administrator for
Equal Opportunity Programs

FOREWORD

The National Aeronautics and Space Administration (NASA) is a Federal agency with a strong tradition of excellence. A key component of this tradition is a close working relationship with the Nation's educational and research institutions. NASA recognizes the crucial contributions that Minority Institutions (MI) make toward fulfilling the Agency's goals of exploration, discovery, and the pursuit of knowledge. NASA's commitment to supporting the efforts of MIs is evidenced by the programs administered through the Agency's Office of Equal Opportunity Programs. The vision of these programs is to ***achieve full participation of MIs in the NASA-sponsored research and education community, striving for academic excellence and outstanding achievements while advancing America's leadership in a competitive scientific and technological global economy.***

In a recent address, NASA Administrator Daniel S. Goldin emphasized the necessity of bringing the very best talents available from all segments of the Nation to bear on the crucial issues facing America's space, science, and technology efforts. The projects described herein, representing the accomplishments of the many faculty and student researchers supported by NASA's minority university research and education programs, amply demonstrate the contributions that MIs are making toward that goal.

NASA's support for MI dates back to the Apollo era. In 1990, NASA established a formal Minority University Research and Education Program (MUREP) under the Office of Equal Opportunity Programs to respond to the Executive Orders (EO) mandating increased Federal support for Historically Black Colleges and Universities (HBCU) (EOs 12232, 12320, 12677, and 12876); Educational Excellence for Hispanic Americans (EOs 12729 and 12900); and Tribal Colleges and Universities (EO 13021). NASA views the involvement of MI's as an opportunity to acquire increased research and development support for NASA's mission needs, as well as an opportunity to promote greater involvement of socially-abd economically-disadvantaged (hereafter referred to as disadvantaged) and/or disabled students in space-related careers.

The institutions that are eligible to participate in NASA's MUREP are HBCU's, Hispanic-Serving Institutions (HSI), Tribal Colleges and Universities, and accredited minority colleges or universities with 50 percent or greater underrepresented minority student enrollment.

The programs described in this report are those that focus on research and development activities. The University Research Centers (URC) at MIs are world-class research centers based at MIs. The Institutional Research Awards (IRA) for MIs are institutional research capability development programs, and the Faculty Awards for Research (FAR) are individual principal investigator grants. Programs focusing on educational outreach are described in the separately published *Precollege and Bridge Programs Performance Report.*

NASA has a long and proud history of MI-based research and technology programs. We are committed to continuing this tradition and serving as a model for minority education and involvement in the Federal sector.

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